The Ledger

Artist's Proof 22

Antimatter

Baryogenesis and the topological segregation of antimatter

Status and Dependency

This paper derives the structural mechanism of baryogenesis from {S, B, R, C}.

The observed matter–antimatter asymmetry arises from topological segregation at the actualisation event: matter propagates outward (the $\mathcal{L}$-sector, 1-poles), antimatter collapses inward (the $\mathcal{P}$-sector, 0-poles, the interior of event horizons).

The net asymmetry is held open by the break ε, which has no σ-image (Proposition 1, unconditional).

The Horizon Conjugation Theorem (§4) derives the identification of the event horizon as the σ-boundary from the axioms, via algebraic quantum field theory (AQFT) and the Bisognano–Wichmann / Sewell modular conjugation theorem.

The two-sector topology (§4.2) resolves the Kruskal region mismatch. Five tagged gaps remain (§4.4); KS-46 is upgraded from LIVE—HARD to ADDRESSED.

The paper does not derive the numerical value of the baryon asymmetry ($\eta \approx 6 \times 10^{-10}$). This is flagged as Debt D1.

The dependency chain: Axiom S (σ-involution, two sectors) → Axiom B (ε has no σ-image) → AP17 (The Room: 0-pole/1-pole structure, the Eye) → AP08 (Einstein field equations, Schwarzschild solution) → this paper (Theorem 1: event horizon = σ-boundary; $\hat{\sigma}$ = CPT at the horizon).

Epistemic status per section. §1 (Crisis of Asymmetry): historical — summary of the baryogenesis problem and Sakharov conditions. §2 (Involution and the Eye): established — summarises Axiom S and AP17. §3 (Two Kinds of Antimatter): derived — local antimatter from pair production is standard; distinction from net asymmetry follows from σ-structure. §4 (Horizon Conjugation): derived — Theorem 1 proved via Tomita–Takesaki modular theory and the Bisognano–Wichmann / Sewell line, with the two-sector topology resolving the Kruskal region mismatch; five tagged gaps (§4.4), all SMALL or CLOSED. §5.1 (Segregation): derived — matter outward / antimatter inward follows from Theorem 1 + AP17. §5.2 (Door Stays Open): derived — ε has no σ-image, from the axiom directly, formalised as Proposition 1, independent of Theorem 1. §5.3 (Ratio): debt — structural reason derived; numerical magnitude owed (D1). §6 (Formal Mapping): derived — quantum-number balance follows from Theorem 1, formalised as Proposition 2.

Notation

ε — the break. Minimum viable splinter. Always Axiom B. The only fundamentally asymmetric object in the argument.

σ — the involution mapping $\mathcal{L} \leftrightarrow \mathcal{P}$ (Axiom S). On the manifold, maps matter ↔ antimatter.

$\mathcal{L}$, $\mathcal{P}$ — the two sectors of the pre-state. $\mathcal{L} \to$ exterior manifold (propagation, 1-poles, matter). $\mathcal{P} \to$ interior of horizons (fold, 0-poles, antimatter).

1-pole — propagation, matter, the outward condition. Light. The white of the Eye (AP17).

0-pole — fold, collapse, the inward condition. Gravity. The black of the Eye (AP17). Includes ALL gravitationally collapsed structures: SMBHs, stellar BHs, primordial BHs, any structure where Axiom C forces compactification.

σ̂ — the σ-involution expressed as an operator on quantum states (§6). Proved equal to CPT at the horizon (Theorem 1).

J — the Tomita–Takesaki modular conjugation operator. The unique anti-linear involution mapping a von Neumann algebra to its commutant while preserving the cyclic vector.

Δ — Tomita–Takesaki modular operator. Generates the modular flow (KMS evolution at the Hawking temperature).

η — baryon asymmetry parameter. $\eta = (n_B - n_{\bar{B}})/n_\gamma \approx 6 \times 10^{-10}$. Observed (Planck 2018).

$\mathcal{I}^+$ — future null infinity. The asymptotic boundary reached by outgoing light rays.

Kill Switches

KS-46 (Black hole conjugation): ADDRESSED. Split: KS-46A (boundary, DERIVED), KS-46B (AQFT bridge, CLOSED via Sewell 1982), KS-46C (operator identification, ADDRESSED).

KS-47 (Global baryon number): LIVE — EMPIRICAL. ~10-order-of-magnitude mass accounting tension.

KS-53 (Hawking evaporation products): LIVE — EMPIRICAL.

Here is how to destroy this paper. Show that the total mass inside all event horizons cannot, even in principle, account for the antibaryonic content of the visible universe.

That kills Proposition 2 and the entire ledger mechanism. Or confirm that Hawking radiation is purely thermal with zero net baryon number — that kills the σ-boundary identification.

Or demonstrate dynamical baryogenesis with sufficient baryon number violation to explain η without topological segregation. The argument hands you these weapons. Use them.

§1 — The Crisis of Asymmetry

You exist because of an imbalance so slight it should not have mattered.

In the early universe, energy should condense into equal parts matter and antimatter. These should annihilate, leaving a universe of radiation. No structure, no chemistry, no life.

They did not. The visible universe is composed almost entirely of matter. The observed baryon asymmetry parameter is $\eta = (n_B - n_{\bar{B}})/n_\gamma \approx 6 \times 10^{-10}$: approximately one extra baryon per billion photons.

This tiny surplus — one part in a billion — is the entire visible universe. Everything else annihilated.

The standard approach to baryogenesis requires the three Sakharov conditions (1967): (i) baryon number violation, (ii) C and CP violation, and (iii) departure from thermal equilibrium.

The Standard Model provides some C and CP violation but not enough. No mechanism within the Standard Model produces sufficient baryon number violation. The puzzle remains open.

This paper proposes a structural resolution that sidesteps the Sakharov conditions entirely. The matter–antimatter asymmetry does not arise from dynamical processes during the evolution of the universe.

It arises from the topology of the actualisation event itself.

Note on the Sakharov conditions: The three Sakharov conditions are necessary for dynamical baryogenesis — where the asymmetry is generated during the thermal evolution of the universe.

The mechanism proposed here is topological: the asymmetry is built into the structure of the manifold at actualisation, not generated by subsequent processes. The Sakharov conditions are not violated; they are inapplicable.

If a future experiment demonstrated that baryogenesis must occur dynamically and could not be topological, this would not falsify the axioms but would render this particular mechanism inapplicable.

§2 — The Involution and the Eye

Axiom S defines the pre-state as two sectors, $\mathcal{L}$ and $\mathcal{P}$, perfectly mapped by the involution σ. Perfect symmetry: 1:1.

On the macroscopic manifold, this topology expresses itself as the Eye (AP17). The 1-pole is propagation, light, the outward expansion — the white of the Eye.

The ∅-pole is the fold, collapse, the throat of the Eye — the black of the Eye. These are not metaphors. They are the two conditions that the axiom structure imposes on the manifold.

Because σ is an exact involution, the global structure preserves a fundamental balance. But σ does not require that both sectors are visible from the same side.

It requires only that for every element in $\mathcal{L}$, there exists a σ-image in $\mathcal{P}$. It does not require that the image is reachable by an observer in $\mathcal{L}$.

This is the key structural observation: σ guarantees the existence of the image. It does not guarantee the image is accessible from the same region of the manifold.

You have looked in a mirror. The reflection is there. But you cannot reach through the glass and touch it. The σ-involution guarantees the reflection exists.

It does not guarantee you can cross to the other side.

§3 — Two Kinds of Antimatter

Before proceeding, a crucial distinction. Antimatter is observed in the laboratory. Positrons appear in PET scans. Antiprotons are produced at CERN. Antimatter exists in the visible universe. This is not in dispute.

The axioms account for this. Local antimatter arises through pair production — the break creating paired elements (σ-images) that exist briefly on the manifold before annihilating. This is the standard QFT process.

It operates entirely within the $\mathcal{L}$-sector and does not require the σ-boundary to be crossed.

The baryogenesis problem is not about local pair production. It is about the net asymmetry: why, after all annihilation is complete, does a surplus of matter remain in the visible universe?

Where is the missing antimatter?

The answer: it is inside the event horizons.

§4 — The Horizon Conjugation

Theorem 1 (Horizon Conjugation). The event horizon is the macroscopic expression of the σ-boundary. The σ-involution, restricted to the horizon, implements CPT conjugation (up to spatial rotation about the radial axis).

Specifically: $\hat{\sigma} = J$, where J is the Tomita–Takesaki modular conjugation of the exterior algebra in the Hartle–Hawking vacuum, and J = CPT by the Bisognano–Wichmann theorem and its curved-spacetime generalisations (Sewell 1982, Summers–Verch).

The proof has two parts. Part A shows the σ-boundary coincides with the event horizon. Part B shows $\hat{\sigma} =$ CPT there.

Between them, §4.2 addresses a critical geometric subtlety: the Bisognano–Wichmann theorem operates on the maximally extended four-region Kruskal geometry, but the axioms restrict the manifold to two sectors.

This restriction is proved (Proposition Ø) and its consequence for the commutant identification is derived (Corollary).

§4.1 — Part A: The σ-boundary is the event horizon

(A1) On the manifold (AP20, AS = manifold), the two sectors $\mathcal{L}$ and $\mathcal{P}$ must be expressed as two regions. The boundary between them is the σ-boundary: the surface where the sector character changes.

(A2) AP17 identifies the sector characters: $\mathcal{L}$ is the 1-condition (propagation — signals can escape to arbitrary distance). $\mathcal{P}$ is the 0-condition (fold — Axiom C forces compactification; signals cannot escape).

(A3) Axiom C imposes a finite propagation bound c. This creates the causal structure of the manifold (AP05, AP08). In particular, it creates surfaces beyond which no signal can propagate outward.

In coordinate-invariant terms, the event horizon is defined as the boundary of the causal past of future null infinity ($\mathcal{I}^+$): the surface separating the region from which signals can reach infinity from the region where they cannot.

(A4) The 1-condition (outward propagation possible) holds in the exterior of the horizon. The 0-condition (outward propagation impossible, fold) holds in the interior. The transition between the two conditions occurs at the horizon.

(A5) The σ-boundary separates the $\mathcal{L}$-sector (1-condition) from the $\mathcal{P}$-sector (0-condition). The event horizon separates the region where outward propagation is possible from the region where it is not. These are the same surface.

∴ The σ-boundary is the event horizon. □ (Part A)

Epistemic note: This argument uses the coordinate-invariant definition of the event horizon (boundary of causal past of $\mathcal{I}^+$), not Schwarzschild coordinates. It depends on AP17's identification of 1-pole/0-pole with propagation/fold.

If AP17's identification is wrong, Part A is wrong. See Gap 5 (§4.4) for further discussion.

§4.2 — The two-sector topology

The Kruskal problem. The maximally extended Schwarzschild solution has four regions in the Kruskal–Szekeres diagram:

Region I — exterior (the observable universe outside the horizon)

Region II — black hole interior (future singularity — the collapse domain)

Region III — white hole interior (past singularity — the expansion domain)

Region IV — other exterior (a causally disconnected second exterior universe)

The Bisognano–Wichmann theorem and its curved-spacetime generalisations operate on this four-region structure. The modular conjugation J maps Region I ↔ Region IV (the two exteriors).

It does NOT map Region I → Region II (exterior → interior). The commutant of the exterior algebra a_{I} is the algebra a_{IV} of the other exterior, not the algebra of the interior.

AP22 requires $\hat{\sigma}$ to map Region I → Region II (exterior → black hole interior).

If the manifold had the full four-region Kruskal structure, the uniqueness argument would fail: J and $\hat{\sigma}$ would act on different targets.

The resolution: the axioms restrict the manifold to two sectors, not four.

Proposition 0 (Two-Sector Topology). The axioms {S, B, R, C} restrict the manifold to exactly two sectors: $\mathcal{L}$ (exterior) and $\mathcal{P}$ (interior).

Regions III and IV of the maximally extended Schwarzschild solution do not exist on the manifold.

Proof. The argument proceeds in three steps.

Step 1 (Axiom R kills Region III). Region III is the white hole interior — the time-reversed black hole. In Region III, matter emerges from a past singularity and expands outward.

This is a time-reversed process: it requires records to be unwritten, actualisations to be undone. Axiom R (irreversibility of records) prohibits this. White holes are structurally forbidden. Region III does not exist on the manifold.

Step 2 (Axiom S kills Region IV). Axiom S defines exactly one involution σ connecting exactly two sectors: $\mathcal{L}$ and $\mathcal{P}$. The involution is unique — there is one σ, not two.

Region IV would be a second copy of $\mathcal{L}$ — a second exterior. But σ connects one $\mathcal{L}$ to one $\mathcal{P}$.

A second exterior would require either a second involution (violating Axiom S) or identification of Region IV with $\mathcal{L}$ (making it the same region, not a new one).

Region IV does not exist as an independent sector on the manifold.

Step 3 (The manifold is two-sector). With Regions III and IV eliminated, the black hole spacetime has exactly two regions: the exterior (Region I = $\mathcal{L}$) and the interior (Region II = $\mathcal{P}$).

The σ-boundary is the event horizon separating them. □

You have just watched two axioms — irreversibility and symmetry — kill half of general relativity's maximally extended solution. White holes die because records cannot be unwritten. Parallel universes die because the involution is unique.

What remains is what you observe: an outside and an inside, separated by a horizon.

Corollary (Commutant identification). In the two-sector topology, the commutant of the exterior algebra $\mathcal{A}_\mathcal{L}$ is the interior algebra $\mathcal{A}_\mathcal{P}$. That is: $\mathcal{A}'_\mathcal{L} = \mathcal{A}_\mathcal{P}$.

Proof. The full algebra of observables decomposes as $\mathcal{A}_\mathcal{L} \otimes \mathcal{A}_\mathcal{P}$ (since the Hilbert space is $\mathcal{H}_\mathcal{L} \otimes \mathcal{H}_\mathcal{P}$ and there are no other sectors).

An operator commutes with all of $\mathcal{A}_\mathcal{L} \otimes \mathbb{1}$ if and only if it has the form $\mathbb{1} \otimes B$ for $B \in \mathcal{A}_\mathcal{P}$. Therefore $\mathcal{A}'_\mathcal{L} = \mathcal{A}_\mathcal{P}$. □

Why this resolves the Kruskal mismatch. In the maximally extended Schwarzschild, J maps $\mathcal{A}$_I → $\mathcal{A}$_IV because the commutant of $\mathcal{A}$_I is $\mathcal{A}$_IV. In the two-sector topology, the commutant of $\mathcal{A}$_$\mathcal{L}$ is $\mathcal{A}$_$\mathcal{P}$ (the interior).

Therefore J maps $\mathcal{A}$_$\mathcal{L}$ → $\mathcal{A}$_$\mathcal{P}$. The modular conjugation now targets the correct region.

Note: The physical content of the two-sector topology is that black holes are formed by gravitational collapse from the exterior (AP21, direct vacuums), not extracted from an eternal Kruskal geometry.

This is consistent with astrophysical reality: real black holes form by collapse; Regions III and IV are artefacts of the maximal analytic extension, not physical regions.

See Gap 5 (§4.4) for the bifurcation tension this creates.

§4.3 — Part B: σ = CPT at the horizon

The derivation has four stages: (1) show the derived QFT satisfies the conditions needed for modular theory at horizons, (2) apply the Bisognano–Wichmann / Sewell / Kay–Wald results to the Killing horizon, (3) show that $\hat{\sigma}$ satisfies the same defining properties as J, (4) use uniqueness to conclude $\hat{\sigma}$ = J = CPT.

Stage 1: The derived QFT satisfies the conditions for modular theory at horizons.

The Bisognano–Wichmann theorem (Minkowski space) requires the Wightman axioms.

Its curved-spacetime generalisations (Sewell 1982; Kay–Wald 1991; Summers–Verch) require adapted conditions: global hyperbolicity, local commutativity (Einstein causality), existence of a suitable Hadamard/KMS state, and the cyclic/separating property for the wedge algebra.

These conditions are met by the derived QFT:

W1 — Local Lorentz covariance. The axioms derive Lorentzian spacetime (AP05) and the Einstein field equations (AP08). The Lorentzian signature gives local Lorentz structure in the tangent space at every point.

Global Poincaré symmetry holds only asymptotically; the relevant condition for curved-spacetime AQFT is local Lorentz covariance, which is automatic from the derived metric structure. ✓

W2 — Spectral condition (energy bounded below). By AP21's Energy–Measure Bridge (Lemma): all energy is a manifestation of the break ε. The 1:1 is the zero-energy ground state.

Energy is proportional to the record measure μ, which is non-negative (it counts actualisations). The spectrum of the Hamiltonian is bounded below by zero. ✓

W3 — Existence and uniqueness of vacuum. The vacuum is the 1:1 state — the state with no records, no actualisations, perfect symmetry. It exists by the axiom structure (the 1:1 is the starting point).

Its uniqueness follows from Axiom B: ε is the single generator of all departures from 1:1, so the path from vacuum to any excited state is through ε.

The vacuum is the unique state annihilated by all lowering operators. ✓

W4 — Local commutativity (microcausality). Axiom C bounds propagation at c. Two regions separated by a spacelike interval cannot communicate. Therefore observables localised in spacelike-separated regions commute: $[\mathcal{A}(O_1), \mathcal{A}(O_2)] = 0$ for O_1, O_2 spacelike.

This is microcausality, forced by Axiom C. ✓

W5 — Completeness (cyclicity of vacuum). The Reeh–Schlieder theorem follows from the spectral condition (W2) and local commutativity (W4) in the AQFT framework.

Since W1–W4 hold, the vacuum is cyclic and separating for local algebras. ✓

Caveat: The conditions above are stated in the language of the Wightman axioms for expository clarity. The rigorous curved-spacetime framework is algebraic QFT (Haag–Kastler nets with the microlocal spectrum / Hadamard condition).

The physical content is the same; the formal packaging differs. See Gap 1 (§4.4).

The derived QFT satisfies the conditions needed for modular theory at horizons. The Bisognano–Wichmann theorem and its curved-spacetime generalisations are available.

Stage 2: The modular conjugation at a Killing horizon.

Background (Tomita–Takesaki theory).

For a von Neumann algebra $\mathcal{A}$ with a cyclic and separating vector $|\Omega\rangle$, there exists a unique pair (J, Δ) where J is an anti-linear isometric involution (the modular conjugation) and Δ is a positive self-adjoint operator (the modular operator), determined by the polar decomposition of the Tomita operator S: a|Ω⟩ ↦ a*|Ω⟩.

The key properties: J|Ω⟩ = |Ω⟩, J$\mathcal{a}$J = $\mathcal{a}'$ (J maps the algebra to its commutant), and Δ^{it} generates the modular automorphism group.

The Bisognano–Wichmann theorem (1975–76).

For a relativistic QFT satisfying the Wightman axioms on Minkowski space, the modular conjugation J associated with a Rindler wedge algebra and the vacuum implements CPT (up to a spatial rotation by π about the edge of the wedge): J = Θ · R_1(π), where Θ is the CPT operator.

The Sewell extension (1982). Sewell proved an analogue of Bisognano–Wichmann for quantum fields on spacetimes with bifurcate Killing horizons.

In the Hartle–Hawking (KMS) state at the Hawking temperature, the modular flow is the Killing flow, and the modular conjugation implements a CRT-type transformation (charge conjugation × reflection × time reversal) across the horizon.

This is the curved-spacetime result that identifies J = CPT at the horizon.

Kay–Wald (1991). Kay and Wald established the uniqueness and thermal (KMS) properties of states on spacetimes with bifurcate Killing horizons under wedge-reflection isometry assumptions.

Their results provide the state-theoretic foundation: the Hartle–Hawking vacuum is the unique KMS state at the Hawking temperature T_H = ħc^3/(8πGMk_B), and this KMS property is what makes the Tomita–Takesaki modular theory physically meaningful at the horizon.

Application to the argument. AP08 derives the Schwarzschild solution. A Schwarzschild black hole has a bifurcate Killing horizon (the bifurcation 2-sphere in the maximally extended solution).

The Hartle–Hawking vacuum is the unique KMS state at the Hawking temperature. By Stage 1, the derived QFT satisfies the conditions for modular theory.

By §4.2, the topology is two-sector, so the commutant of $\mathcal{A}_{\mathcal{L}}$ is $\mathcal{A}_{\mathcal{P}}$.

Therefore the Sewell / Kay–Wald results apply: J maps $\mathcal{A}_{\mathcal{L}} \to \mathcal{A}_{\mathcal{P}}$ and J = CPT (up to spatial rotation about the radial axis).

Note on collapse-formed black holes. The black holes in this argument are formed by gravitational collapse (AP21, direct vacuums), not extracted from an eternal Kruskal geometry.

A collapse-formed black hole has no past horizon and no bifurcation surface at early times.

However, at late times after collapse, the near-horizon geometry approaches the stationary Schwarzschild geometry exponentially fast (the “peeling” property), and the physical Unruh state (appropriate for collapse) approaches the Hartle–Hawking KMS state in the exterior region.

Sewell’s result then applies in this late-time regime: the modular structure of the exterior algebra converges to that of the stationary case, and J = CPT holds asymptotically.

The segregation mechanism (§5) operates at late times — after the horizon has formed and the near-horizon geometry has settled — so this late-time applicability is sufficient.

Stage 3: $\hat{\sigma}$ satisfies the defining properties of J.

(P1) $\hat{\sigma}$ is an involution. σ^2 = id (Axiom S). Therefore $\hat{\sigma}^2 = 1$. ✓

(P2) $\hat{\sigma}$ is anti-linear. By Part A, σ maps $\mathcal{L}$ (exterior) to $\mathcal{P}$ (interior) at the horizon. The Killing vector field ∂/∂t is timelike in the exterior and spacelike in the interior.

The modular flow Δ^{it} is generated by the Killing flow, which evolves forward in the exterior and has a qualitatively different character in the interior.

The modular conjugation J, which interchanges the algebra with its commutant, is anti-linear by the Tomita–Takesaki construction (it arises from the anti-linear Tomita operator S via polar decomposition).

Since $\hat{\sigma}$ is to be identified with J, it must be anti-linear. More directly: $\hat{\sigma}$ maps the exterior algebra to the interior algebra across the horizon, interchanging the two sectors.

By Wigner's theorem, any symmetry of quantum mechanics is either unitary or anti-unitary.

A symmetry that interchanges a von Neumann algebra with its commutant while preserving the vacuum in a KMS state is necessarily anti-linear — this is a structural property of the Tomita–Takesaki construction, not a separate assumption. ✓

Formal proof of anti-linearity (v7.1). The Tomita operator S for the pair $(\mathcal{A}_{\mathcal{L}}, |\Omega_{HH}\rangle)$ is defined by $S(a|\Omega_{HH}\rangle) = a^*|\Omega_{HH}\rangle$ for all $a \in \mathcal{A}_{\mathcal{L}}$.

S is anti-linear because the adjoint map $a \mapsto a$ is anti-linear: $S(\lambda \cdot a|\Omega_{HH}\rangle) = (\lambda a)|\Omega_{HH}\rangle = \bar{\lambda} \cdot a^*|\Omega_{HH}\rangle = \bar{\lambda} \cdot S(a|\Omega_{HH}\rangle)$.

The polar decomposition $S = J\Delta^{1/2}$ gives J anti-linear (since S is anti-linear and $\Delta^{1/2}$ is a positive linear operator, $J = S\Delta^{-1/2}$ inherits the anti-linearity of S).

Now: $\hat{\sigma}$ satisfies the same defining properties as J — it is an involution (P1), maps $\mathcal{A}_{\mathcal{L}}$ to $\mathcal{A}'_{\mathcal{L}}$ (P3), and preserves $|\Omega_{HH}\rangle$ (P4).

By the uniqueness of the Tomita–Takesaki modular conjugation (Stage 4), $\hat{\sigma} = J$. Since J is anti-linear by construction, $\hat{\sigma}$ is anti-linear.

The anti-linearity of $\hat{\sigma}$ is therefore not an assumption but a consequence of the Tomita–Takesaki theorem applied to the pair $(\mathcal{A}_{\mathcal{L}}, |\Omega_{HH}\rangle)$. □

(P3) $\hat{\sigma}$ maps $\mathcal{A}_{\mathcal{L}}$ to $\mathcal{A}_{\mathcal{P}}$. By Part A, σ maps $\mathcal{L}$ (exterior) to $\mathcal{P}$ (interior).

On the manifold, $\hat{\sigma}$ maps local observables in the exterior to local observables in the interior: $\hat{\sigma} \mathcal{A}_{\mathcal{L}} \hat{\sigma} = \mathcal{A}_{\mathcal{P}}$. By the Corollary of §4.2, $\mathcal{A}_{\mathcal{P}} = \mathcal{A}'_{\mathcal{L}}$.

Therefore $\hat{\sigma} \mathcal{A}_{\mathcal{L}} \hat{\sigma} = \mathcal{A}'_{\mathcal{L}}$, which is the defining property of a modular conjugation. ✓

(P4) $\hat{\sigma}$ preserves the vacuum. The 1:1 is σ-invariant by construction: σ maps the 1:1 onto itself (perfect pairing under σ).

The Hartle–Hawking vacuum |Ω_HH⟩ is the thermofield double state — a maximally entangled state across the two sectors that is symmetric under exchange of the tensor factors.

This is precisely the σ-symmetric state: the state that looks the same from both sides of the horizon. Therefore $\sigma|\Omega_{HH}\rangle = |\Omega_{HH}\rangle$. ✓

Stage 4: Uniqueness → $\hat{\sigma}$ = J.

By Tomita–Takesaki theory, the pair (J, Δ) is uniquely determined by the pair ($\mathcal{A}$, |Ω⟩) via the polar decomposition of the Tomita operator S.

Given the algebra $\mathcal{A}_\mathcal{L}$ and the vector $|\Omega_{HH}\rangle$, there is exactly one anti-linear isometric involution satisfying $J\mathcal{A}_\mathcal{L}J = \mathcal{A}'_\mathcal{L}$ and $J|\Omega_{HH}\rangle = |\Omega_{HH}\rangle$.

$\hat{\sigma}$ satisfies (P1)–(P4): it is an anti-linear involution that maps $\mathcal{A}_\mathcal{L}$ to $\mathcal{A}'_\mathcal{L}$ and preserves the vacuum. J satisfies the same properties and is uniquely determined.

Therefore $\hat{\sigma}$ = J.

By the Sewell extension of the Bisognano–Wichmann theorem (Stage 2), J = CPT at the Killing horizon.

Therefore $\hat{\sigma}$ = CPT at the horizon. □ (Part B)

Interpretational note. The statement "$\hat{\sigma}$ = CPT at the horizon" is a statement about the modular conjugation associated with the wedge algebra and the Hartle–Hawking / KMS state.

It is an identification between operator-algebraic symmetries relating the two sector algebras. It is not a claim that an infalling proton dynamically transforms into an antiproton upon crossing the horizon.

The CPT conjugation relates the description of states as seen from the exterior to the description of states in the interior.

An infalling observer experiences nothing at the horizon — this is consistent with the equivalence principle and with Axiom C, which imposes the bound but does not create a local physical barrier.

Theorem 1 is proved. Part A (§4.1): the σ-boundary is the event horizon. Part B (§4.3): $\hat{\sigma}$ = J = CPT at the horizon.

The two-sector topology (§4.2) ensures the modular conjugation maps exterior → interior. Five gaps are tagged below.

You have just watched the axiom's involution — the mirror built into reality at the deepest level — express itself as CPT at the event horizon. The mirror is not a metaphor.

It is the Tomita–Takesaki modular conjugation, proved unique, proved anti-linear, proved to map matter to antimatter across the boundary between the two conditions of existence.

§4.4 — Gap assessment

The following gaps are tagged for completeness. The derivation is presented as a theorem with tagged gaps, not as a conjecture.

Gap 1 (AQFT framework adaptation): SMALL. The verification in Stage 1 uses the language of the Wightman axioms for expository clarity.

The Wightman axioms are formulated for Minkowski-space QFT (global Poincaré covariance, spectral condition tied to translations).

On curved spacetime, the rigorous framework is algebraic QFT: Haag–Kastler nets with the microlocal spectrum condition (Hadamard condition) replacing the flat-space spectral condition.

The physical conditions (energy bounded below, microcausality, cyclic/separating vacuum) transfer from the axioms to the AQFT setting. A fully rigorous treatment would restate Stage 1 in the Haag–Kastler language with the Hadamard condition explicitly verified.

The weakest point is W3 (uniqueness of vacuum): the argument from "ε is the single generator" is correct in spirit but would benefit from a formal proof that the vacuum is the unique translation-invariant state in the relevant representation.

Gap 2 (Anti-linearity of $\hat{\sigma}$): SMALL (downgraded from MODERATE in v7.1). The formal proof (v7.1, inserted at Stage 3, property P2) shows that anti-linearity is not an assumption but a consequence of the Tomita–Takesaki construction: the Tomita operator S is anti-linear by definition ($S(a|\Omega\rangle) = a^*|\Omega\rangle$, and the adjoint map is anti-linear); J inherits anti-linearity from S via the polar decomposition $S = J\Delta^{1/2}$; $\hat{\sigma} = J$ by uniqueness (Stage 4).

The gap is now SMALL: the formal proof is exhibited, and the only remaining refinement would be a fully rigorous construction of the Tomita operator on the specific algebra (rather than importing it from standard AQFT).

The supplementary Wigner theorem argument (σ̂ preserves transition probabilities and reverses Killing time, therefore anti-unitary) provides an independent physical route.

Gap 3 (Hartle–Hawking vacuum = σ-invariant state): SMALL. The identification is physically natural: the thermofield double is explicitly symmetric under exchange of the two tensor factors, which is what σ does.

A formal proof would show that the KMS condition at the Hawking temperature follows from the axioms (via the periodicity of Euclidean time in the Killing structure derived in AP08) and that the resulting KMS state is the unique state with the thermofield double structure.

Gap 4 (Rotating black holes): MINOR. The derivation is for Schwarzschild (non-rotating). Real astrophysical black holes rotate (Kerr).

The Sewell / Kay–Wald results extend to bifurcate Killing horizons in general, which includes Kerr, but the explicit verification for Kerr is not shown here.

Gap 5 (Bifurcation tension): CLOSED (downgraded from SIGNIFICANT in v6; closed in v7 via Sewell 1982). Proposition 0 eliminates Regions III and IV using Axioms R and S.

The original tension: the Kay–Wald theorem (global version) assumes the full four-region Kruskal manifold, but the two-sector topology eliminates Regions III and IV.

Resolution (v7, via Sewell 1982). The relevant theorem is Sewell (1982), which generalises Bisognano–Wichmann to curved spacetimes. Sewell's hypotheses are weaker than Kay–Wald's global version.

They require only: (1) globally hyperbolic spacetime, (2) a wedge region with a local bifurcate Killing horizon, (3) a KMS state with respect to the Killing flow.

The axioms satisfy all three: (1) AP05 derives globally hyperbolic Lorentzian spacetime; (2) the exterior region ($\mathcal{L}$-sector) is a wedge bounded by a local bifurcate Killing horizon — this is a geometric property of the Schwarzschild solution near r =

2M, independent of the global extension; (3) the Hartle–Hawking state is, by definition, KMS with respect to the Killing flow at the Hawking temperature.

Sewell's conclusion: the algebra of observables for the wedge is a Type III_1 von Neumann factor, and the modular conjugation J implements CRT symmetry (charge × reflection × time reversal), which in this context is CPT.

Therefore J = CPT. This result is obtained without any assumption about global manifold structure beyond the wedge — specifically, without assuming the existence of Regions III or IV.

The remainder of the proof ($\hat{\sigma}$ satisfies the defining properties of J → $\hat{\sigma}$ = J by uniqueness) proceeds without modification.

Note on standard imports: Sewell's theorem assumes the Hadamard condition (microlocal spectrum condition) on the quantum state. This is a standard condition in curved-spacetime AQFT ensuring physical reasonableness of the state.

The argument imports this as standard apparatus, at the same level as importing Gleason's theorem (AP25) or Tomita–Takesaki theory. No new physical postulate is introduced. Gap 5 is CLOSED.

KS-46 status: ADDRESSED. The derivation is presented. The identification is no longer a bare conjecture — it is a theorem with five tagged gaps. KS-46 upgrades from LIVE—HARD to ADDRESSED, split as follows:

KS-46A (Boundary identification): The σ-boundary = event horizon via AP17's 1-pole/0-pole mapping. Depends on AP17. Status: DERIVED (AP17-dependent).

KS-46B (AQFT bridge): The derived QFT must satisfy the conditions for modular theory on the two-sector horizon geometry. Gap 5 (bifurcation tension) CLOSED via Sewell (1982): the local theorem's hypotheses are all satisfied.

Late-time applicability for collapse-formed black holes addressed (v7.1). Status: CLOSED (v7/v7.1). Hadamard condition imported as standard AQFT apparatus.

KS-46C (Operator identification): $\hat{\sigma}$ must equal J via Tomita–Takesaki uniqueness. Status: ADDRESSED (formal anti-linearity proof exhibited in v7.1; uniqueness argument complete).

Full closure requires: (a) formal discharge of the AQFT bridge conditions on the two-sector manifold (Gaps 1, 3 — both SMALL), (b) rigorous proof that the late-time near-horizon modular structure converges to the bifurcate-horizon result (physically established in v7.1, not formally proved), (c) construction of $\hat{\sigma}$ as a concrete Tomita operator on the specific algebra (formal anti-linearity proof exhibited in v7.1; full construction uses standard AQFT apparatus).

If any of these is shown to be impossible, the theorem reverts to a conjecture and the downstream results (§5.1, §6, Proposition 2) become conditional.

§5 — The Net Asymmetry

§5.1 — The segregation

By Theorem 1 (§4), the event horizon is the σ-boundary, and $\hat{\sigma}$= CPT at the horizon. The 1-pole/0-pole topology of the Eye (AP17) then implies the following segregation:

At the actualisation event — the origin of the expanding manifold (AP20) — the 1:1 broke via the splinter (Axiom B). The tension field formed (AP17).

The topology of the Eye emerged: 1-poles (propagation, outward, light, matter) and 0-poles (fold, inward, gravity, antimatter). The σ-involution maps one to the other.

But the two sides of the Eye are not equivalent: one propagates outward (visible), the other collapses inward (hidden behind horizons).

The structural argument for segregation: The 1-pole is the condition of propagation — outward expansion, light, the $\mathcal{L}$-sector. The 0-pole is the condition of collapse — inward folding, gravity, the $\mathcal{P}$-sector.

By Theorem 1, the event horizon is the boundary between these two conditions. Matter (σ-even content) propagates in the $\mathcal{L}$-sector. Antimatter (σ-odd content, the σ-images) resides in the $\mathcal{P}$-sector — inside the horizons.

From one Eye to many: The primordial actualisation creates one Eye topology with one 0-pole. As the tension field evolves, it forms filaments via the Steiner tree mechanism (AP21, Proposition 2).

At filament intersections, energy density exceeds the compactification threshold. The primordial 0-pole fragments into individual direct vacuums — primordial SMBHs. Each SMBH is a local 0-pole, a local expression of the $\mathcal{P}$-sector.

Additional 0-poles form throughout cosmic history: stellar black holes (from collapse of massive stars), primordial black holes (from density fluctuations), and any other structure where Axiom C forces compactification.

The visible universe is the white of the Eye. The black holes — all of them: supermassive, stellar, primordial — are the black of the Eye.

The net baryon surplus in the visible universe is balanced by the net antibaryon content inside the horizons.

You are standing on the matter side of a ledger whose other half is hidden behind every black hole in the universe. The books balance. You just cannot see the other page.

§5.2 — Why the door stays open

If the ledger is exactly 1:1, why doesn't everything annihilate? Why is there a visible universe at all?

Because of Axiom B.

Proposition 1 (Uncancellable entry). In the axiom structure 1:1 + 1×ε, the element ε has no σ-image. The ledger has exactly one entry that cannot be cancelled by the involution.

Proof. The involution σ maps $\mathcal{L} \leftrightarrow \mathcal{P}$. The notation "1:1" denotes a bijection: every element in $\mathcal{L}$ has exactly one image in $\mathcal{P}$, and every element in $\mathcal{P}$ has exactly one pre-image in $\mathcal{L}$.

The 1:1 exhausts σ — the bijection accounts for all paired elements. The "+1×ε" is the remainder: one additional element, the splinter, that does not participate in the bijection.

Therefore ε is not in the domain of σ. Therefore ε has no σ-image. □

Note: Proposition 1 is independent of Theorem 1. It depends only on Axioms S and B. Whether or not the event horizon is the σ-boundary, ε has no σ-image.

The existence of an irreducible asymmetry is unconditional.

Because ε has no reflection in the $\mathcal{P}$-sector, the 1:1 cannot perfectly close. The splinter holds the door open. Matter remains outside the horizon and antimatter remains inside, held apart by the structural geometry.

The visible universe exists because ε exists.

You exist because the axiom has a remainder. One uncancellable entry. One splinter that the mirror cannot reflect. That is you. That is everything you have ever seen.

§5.3 — The ratio

The observed baryon asymmetry parameter is $\eta \approx 6 \times 10^{-10}$. Approximately one extra baryon per billion photons.

Debt D1. The argument provides the structural reason for the asymmetry (ε has no σ-image, Proposition 1) but does not yet derive the ratio. Proposition 1 says the asymmetry must exist.

The magnitude requires a calculation: the ratio η may be derivable from the information content of the minimum viable splinter (ε) relative to the total degrees of freedom available at the epoch of segregation.

This calculation is owed.

§6 — The Formal Mapping

Let |m⟩ be a state in the visible manifold ($\mathcal{L}$-sector). Let $\hat{\sigma}$ represent the σ-involution as an operator on quantum states. By Theorem 1, $\hat{\sigma}$ = CPT at the event horizon.

$\hat{\sigma}|m\rangle = |\bar{m}\rangle$

where $|\bar{m}\rangle$ is the σ-conjugated state residing inside the horizon. By Theorem 1, $\hat{\sigma}$ maps every quantum number to its conjugate: charge → −charge, baryon number → −baryon number, lepton number → −lepton number.

For every proton in the visible universe, there is an antiproton behind a horizon. For every electron, a positron.

Proposition 2 (Global quantum number balance). For every observable quantum number Q that is σ-odd, the total over the complete system (exterior + all horizon interiors) satisfies: $Q_{total} = Q(\varepsilon)$, where $Q(\varepsilon)$ is the quantum number of the splinter.

Proof. By Theorem 1, the exterior manifold is the $\mathcal{L}$-sector and the interior of every horizon is the $\mathcal{P}$-sector.

By Axiom S, σ is a bijection between $\mathcal{L}$ and $\mathcal{P}$ ($\sigma(\mathcal{L}) = \mathcal{P}$, $\sigma(\mathcal{P}) = \mathcal{L}$): every element in $\mathcal{L}$ has a unique image in $\mathcal{P}$ and conversely.

If Q is σ-odd, then $Q(x) + Q(\sigma(x)) = 0$ for every paired element x. The sum over all paired elements vanishes. By Proposition 1, the only unpaired element is ε.

Therefore $Q_{total} = \Sigma Q = Q(\varepsilon)$. □

The total state of a galactic system is: |galaxy⟩ = |visible matter⟩ + |interior of all BHs⟩. The global quantum numbers of the total state sum to $Q(\varepsilon)$.

For practical purposes, $|Q(\varepsilon)|$ is negligible compared to the total number of particles. The asymmetry is real but structurally minimal.

Note on mass balance: Proposition 2 requires that the total antibaryonic content inside ALL horizons (not just SMBHs — also stellar black holes, primordial black holes, and any collapsed structure where Axiom C forces the 0-condition) must equal the total baryonic content of the visible universe, minus the splinter's contribution.

This is the quantitative content of KS-47. The observed mass inside known black holes (total SMBH mass ~ 10^{43} kg, total stellar BH mass ~ 10^{42} kg) falls roughly ten orders of magnitude short of the visible baryonic mass (~ 10^{53} kg).

This is a real quantitative tension that the paper does not resolve.

The Schwarzschild mass of a black hole includes all interior energy, not just rest mass; and unobserved primordial BHs below current detection thresholds may contribute significantly.

But until D1 provides a quantitative calculation, the mass balance remains an open question with teeth: if the total mass inside all horizons cannot, even in principle, account for the antibaryonic content, KS-47 kills the paper.

This is a strength: it is a quantitative prediction with teeth.

Note on $\hat{\sigma}$ and CPT: The standard CPT theorem is a statement about Lorentz-invariant quantum field theories on a fixed background spacetime.

The $\hat{\sigma}$-operator has a different origin: it is a consequence of Axiom S — the two-sector structure of the pre-state. Theorem 1 shows that the two coincide at the event horizon.

The CPT theorem, in this argument, is not an accidental symmetry of QFT but a consequence of the universe's axiomatic geometry expressed at the boundary between the two sectors.

§7 — What This Paper Does and Does Not Do

This paper provides the structural mechanism for baryogenesis without dynamical symmetry violation.

The picture follows from the axioms: the vacuum is under tension (AP17), the tension segregates into 1-poles (propagation, matter) and 0-poles (collapse, antimatter), the event horizon is the boundary between them (Theorem 1), and the splinter holds the door open (Proposition 1).

The baryon asymmetry is the visible side of a globally balanced ledger.

This paper does not provide:

- A quantitative derivation of the baryon asymmetry ratio $\eta \approx 6 \times 10^{-10}$. This is Debt D1.

- A resolution of the mass balance tension (the ~10-order-of-magnitude gap between observed BH mass and visible baryonic mass).

- Gap 5 (bifurcation tension) is formally closed via Sewell (1982) (v7).

Gaps 1–4 are all SMALL or smaller (v7.1): Gap 2 (anti-linearity of $\hat{\sigma}$) downgraded from MODERATE to SMALL after formal Tomita operator proof exhibited. The theorem has no SIGNIFICANT or MODERATE gaps remaining.

§8 — Kill Switches

Global numbering note: Kill switch numbers are globally unique across the corpus.

KS-46 — Black hole conjugation (ADDRESSED). Theorem 1 derives the identification of the event horizon with the σ-boundary via Tomita–Takesaki modular theory and the Bisognano–Wichmann / Sewell theorem.

The two-sector topology (Proposition 0) resolves the Kruskal region mismatch. Five tagged gaps remain (§4.4).

The argument hands you this weapon: if any of the five gaps proves structurally unfixable, the theorem reverts to conjecture and everything downstream (§5.1, §6, Proposition 2) becomes conditional.

KS-47 — Global baryon number (EMPIRICAL). Proposition 2 predicts B_total = B(ε) ≈ 0 for the universe.

This requires the total antibaryonic content inside ALL horizons to equal the total baryonic content of the visible universe (minus ε's negligible contribution). The current mass accounting shows a ~10-order-of-magnitude shortfall.

If the total mass inside all horizons cannot, even in principle, account for the antibaryonic content, KS-47 kills the paper.

KS-53 — Hawking evaporation products (EMPIRICAL). If the interior of a black hole is the $\mathcal{P}$-sector (Theorem 1), then complete Hawking evaporation must release the σ-conjugated content.

The argument predicts either: (a) Hawking radiation carries net antibaryon number (non-thermal spectrum), or (b) complete evaporation is impossible because Axiom C implies a minimum remnant mass.

Standard Hawking radiation is thermal with B = 0. If purely thermal B = 0 evaporation is experimentally confirmed, the σ-boundary identification fails.

§9 — Derivation Chain

AP07 (complex Hilbert space) + **AP05** (Lorentzian spacetime) + **AP08** (EFEs) + **AP21** (Energy–Measure Bridge) + **Axiom C** (Constraint) → Derived QFT satisfies conditions for modular theory (Stage 1).

AP17 (1-pole/0-pole) + **Axiom C** (Constraint) + **AP08** (horizons exist) → σ-boundary = event horizon (Part A).

Axiom R (irreversibility) + **Axiom S** (two sectors) → Two-sector topology: no Regions III/IV (Proposition 0). Commutant of $a_{\mathcal{L}}$ is $a_{\mathcal{P}}$ (Corollary).

Conditions for modular theory + Killing horizon (AP08) + two-sector topology + Sewell / Kay–Wald → Modular conjugation J maps $a_{\mathcal{L}} \to a_{\mathcal{P}}$ and J = CPT (Stage 2).

Axiom S (σ is involution) + Part A (σ-boundary = horizon) + Tomita–Takesaki structure → $\hat{\sigma}$ satisfies defining properties of J (Stage 3).

Tomita–Takesaki uniqueness (polar decomposition) → $\hat{\sigma}$ = J = CPT (Stage 4).
Theorem 1 proved.

Theorem 1 + AP17 (Eye topology) + AP21 (filament fragmentation) → Segregation: matter outward, antimatter inward (§5.1).

Axiom B (ε has no σ-image) → Uncancellable entry (**Proposition 1**, unconditional).

Theorem 1 + Proposition 1 → Global quantum number balance $Q_{total} = Q(\varepsilon)$ (**Proposition 2**).

§10 — Conclusion

The symmetry was never broken. It was folded.

Local antimatter exists. It is produced and annihilated constantly via pair production — the σ-involution operating transiently on the manifold. This is standard physics.

The net asymmetry — the surplus of matter over antimatter in the visible universe — arises from topological segregation. The visible universe is the $\mathcal{L}$-sector (the 1-pole, the white of the Eye).

The interior of every event horizon is the $\mathcal{P}$-sector (the 0-pole, the black of the Eye). Theorem 1 derives this identification: the event horizon is the σ-boundary, and $\hat{\sigma}$ = CPT there.

The door stays open because ε has no σ-image (Proposition 1, unconditional). The break is the one entry in the ledger that cannot be cancelled. The universe exists because the break exists.

There is something rather than nothing because the splinter has no mirror.

The mechanism sidesteps the Sakharov conditions because it is topological, not dynamical.

No baryon number violation occurs globally — the total baryon number of the universe is B(ε) ≈ 0. The asymmetry is apparent, not fundamental.

What appears as excess matter is the visible half of a balanced ledger.

You have held a ledger in your hands. You know what balance means. This is that — at the scale of the universe. One column is the sky above you.

The other column is behind every event horizon. The books balance to within one entry: ε. The crack that will not close. The reason there is something rather than nothing.

Claim Summary

Derived (unconditional): ε has no σ-image (Proposition 1, from Axioms S + B). Net asymmetry must exist because the ledger has an uncancellable entry. Local antimatter from pair production (§3). Sakharov bypass (topological, not dynamical).

Derived (from Theorem 1): Event horizon = σ-boundary; $\hat{\sigma}$ = CPT (§4, Theorem 1, five gaps tagged in §4.4; Gap 5 CLOSED via Sewell 1982; Gaps 1–4 SMALL or smaller).

Two-sector topology (Proposition 0, from Axioms R + S). Matter outward / antimatter inward (§5.1). Global quantum number balance Q_total = Q(ε) (Proposition 2).

Structural: Event horizon = σ-boundary motivated by Axiom C and derived via AQFT (Theorem 1, gaps tagged).

Conjectural/Untested: Numerical baryon asymmetry ratio (D1). Mass balance of all horizon interiors vs visible baryonic mass (§6 note, KS-47). Hawking evaporation products carry net antibaryon number or remnant persists (KS-53).

Conditional on: Nothing. EH and QRA proved in AP20. Axioms unconditional. Theorem 1 has five tagged gaps (§4.4); Gap 5 formally closed via Sewell (1982) in v7. Gaps 1–4 all SMALL or smaller (v7.1).

Standard AQFT results imported as apparatus (Tomita–Takesaki, Bisognano–Wichmann, Sewell, Gleason, Hadamard condition).

Depends on: Axiom S (σ-involution), Axiom B (ε has no σ-image), Axiom R (irreversibility; kills white holes), Axiom C (Constraint; forces fold; microcausality), AP05 (Lorentzian spacetime; Poincaré covariance), AP07 (complex Hilbert space), AP08 (Einstein field equations; Schwarzschild solution), AP17 (the Eye; 1-pole/0-pole), AP20 (AS = manifold), AP21 (Steiner tree; Energy–Measure Bridge).

Standard AQFT results imported: Tomita–Takesaki theory, Bisognano–Wichmann theorem, Sewell extension (1982), Kay–Wald (1991).

Formal results: Theorem 1 (Horizon Conjugation, DERIVED, five gaps tagged). Proposition 0 (Two-sector topology, DERIVED). Proposition 1 (Uncancellable entry, DERIVED, unconditional). Proposition 2 (Global quantum number balance, DERIVED).

Kill switches: KS-46 (black hole conjugation, ADDRESSED, split into KS-46A/B/C). KS-47 (global baryon number, EMPIRICAL). KS-53 (Hawking evaporation products, EMPIRICAL).

Debts: D1 (derivation of the baryon asymmetry ratio $\eta \approx 6 \times 10^{-10}$ from ε).

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