Causally Separated Conjugate Universes: Opposite Baryon Asymmetry and Portal-Regulated Annihilation under Multiverse Balance Laws

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Abstract

We formulate a phenomenological model in which a common cosmological seed produces two conjugate universe branches with equal-magnitude and opposite-sign baryon asymmetries. Each branch has an ordinary $3+1$ dimensional Lorentzian spacetime, one future-directed time orientation, and positive matter-antimatter energy. With a branch label $r = \pm 1$, the signed excess is $\eta_{B,r} = rb$, where $b > 0$. The $r = -1$ branch is therefore antimatter dominated, not a negative-mass or negative-energy universe. Ordinary annihilation within each branch removes the symmetric baryon-antibaryon population and leaves a residual proportional to $|\eta_B|$. Possible inter-branch interaction is encoded by

$$\Gamma_{+-} = \Omega(d)\langle \sigma v \rangle n_+ n_-.$$

We distinguish three mutually consistent models: strict separation with $\Omega = 0$; a weak portal with $0 < \Omega \ll 1$ and small integrated optical depth; and transient contact for which $\Omega > 0$ only near a bounce or brane-collision event. In a microscopic portal theory, the densities and distance entering this rate must be defined in a common contact or mediator geometry. Annihilation converts positive rest energy into radiation and other products; it does not erase energy, spacetime, or a universe. We incorporate this conversion into an open-subsystem energy ledger, give a nonnegative coarse-grained entropy-production term, and embed the pair in a cyclic genome based on $b = |\eta_B|$. The strict model is a consistency construction without direct cross-branch observables. Portal extensions are conditionally testable through baryon depletion, radiation injection, spectral distortions, expansion-history changes, diffuse high-energy backgrounds, and gravitational waves.

Keywords: baryon asymmetry; antimatter; multiverse; cyclic cosmology; causal separation; annihilation; portal interaction; entropy balance

1 Introduction

The observable Universe contains far more baryonic matter than antibaryonic matter. Its baryon asymmetry is conventionally written

$$\eta_B \equiv \frac{n_B - n_{\bar{B}}}{n_\gamma}, \tag{1}$$

where n_B, $n_{\bar{B}}$, and n_γ are the baryon, antibaryon, and photon number densities. Cosmological analyses give a post-annihilation value of order 6×10^{-10} [7, 8]. Although small, a nonzero asymmetry is sufficient to leave an unmatched baryonic population after the initially abundant symmetric component annihilates. Explaining its microscopic origin requires baryon-number violation, departures from thermal equilibrium, and the relevant discrete-symmetry violation in the standard Sakharov picture [6].

This paper asks a complementary question: if one universe branch acquires $\eta_B > 0$, can a paired branch acquire $\eta_B < 0$? The intuitive picture resembles the two faces of a coin, but neither face is absolute. Relabeling the branches must leave the pair description unchanged. We therefore call them *conjugate branches* rather than front and back universes.

Table 1: Core notation and physical meaning. The superscript (c) denotes a density represented in a common contact or mediator volume.

Symbol	Type or unit	Meaning
$r = \pm 1$	branch label	Matter-dominated (+) or antimatter-dominated (−) residual
$\eta_{B,r}$	dimensionless	Signed baryon-to-photon excess, $\eta_{B,r} = rb$
$\mathcal{Q}_r$	particle number	Extensive asymmetry charge on a branch hypersurface
λ	order variable	Monotonic label of the ensemble or cyclic history
τ_c	time	Proper time of an effective contact layer, when one exists
d	model dependent	Separation in a common bulk or mediator geometry; undefined for a bare disjoint union
$\Omega(d)$	dimensionless	Overlap or portal factor, $0 \le \Omega \le 1$
Γ_{+-}	volume^{-1} time^{-1}	Cross-branch annihilation-event rate density
$\mathcal{A}_{+-}$	order^{-1}	Net number of cross-branch events per increment $\mathrm{d}\lambda$

Two qualifications are essential. First, antimatter is not negative-mass matter. Antiparticles have positive rest energy, and antihydrogen has been observed to accelerate downward in Earth's gravitational field within current experimental precision [10]. A branch with $\eta_B < 0$ is an antimatter-dominated universe, not a universe with negative gravitational energy. Second, matter-antimatter annihilation does not turn energy into nothing. It converts rest and kinetic energy into photons and other particles. Even complete depletion of a massive component leaves the reaction products and their stress-energy.

The construction extends five companion manuscripts [1, 2, 3, 4, 5]. Paper I introduced a light-chronometric description of finite causal tracks. Paper II described cycle-to-cycle drift through effective extra spatial freedom, baryon asymmetry, and residual memory. Paper III retained ordinary 3 + 1 spacetime and represented cyclic history as a monotonically ordered sequence rather than an extra time direction. Paper IV studied operational propagation freeze-out in an effective black-hole core. Paper V treated universes as open subsystems while imposing phenomenological energy closure on a larger ensemble.

The present paper adds a seed-and-portal layer. Its aims are to: (i) separate signed baryon excess from positive energy; (ii) define an equal-and-opposite pair source; (iii) show how within-branch annihilation leaves conjugate residuals; (iv) state a dimensionally consistent cross-branch annihilation law; (v) classify exact, weak, and transient interaction regimes; and (vi) preserve energy and entropy accounting. This is a phenomenological framework, not a derivation from a fundamental action. It neither proves that a partner universe exists nor selects a unique bounce, topology, or mediator.

2 Definitions and causal scope

2.1 Signed excess, positive density

For branch $r \in \{+1, -1\}$, define

$$q_{B,r} \equiv n_{B,r} - n_{\bar{B},r} = \eta_{B,r} n_{\gamma,r}, \qquad \eta_{B,r} = rb, \qquad b > 0. \tag{2}$$

The sign of $q_{B,r}$ selects the majority population. By contrast, the baryon-antibaryon energy density is positive:

$$\rho_{b,r} = m_B(n_{B,r} + n_{\bar{B},r}) + \rho_{\mathrm{kin},r} \ge 0, \tag{3}$$

in units with $c = 1$ except where it is shown explicitly. After efficient symmetric annihilation,

$$\rho_{\mathrm{res},r} \simeq m_B |n_{B,r} - n_{\bar{B},r}| = m_B b\, n_{\gamma,r} > 0. \tag{4}$$

Thus a signed charge density may scale as $q_B \propto \eta_B a^{-3}$, whereas the gravitating residual density scales as $\rho_{\mathrm{res}} \propto |\eta_B| a^{-3}$. If all other CP-even densities agree, conjugate branches source the same Friedmann background at this level.

2.2 Paired state space

For pair i, let

$$\mathcal{P}_i = (U_{i,+}, U_{i,-}), \qquad \mathcal{M}_i = \mathcal{M}_{i,+} \sqcup \mathcal{M}_{i,-}. \tag{5}$$

Each component carries an ordinary Lorentzian metric $g_{i,r}$ and a local future-directed chronometric variable satisfying

$$\frac{\mathrm{d}\tau_{i,r}}{\mathrm{d}\lambda} > 0. \tag{6}$$

The common order variable does not constitute an additional timelike axis. In the strict model no causal curve connects the components:

$$J^+(p) \cap \mathcal{M}_{i,-r} = \varnothing \quad \text{for all } p \in \mathcal{M}_{i,r}. \tag{7}$$

There is then no ordinary spatial distance between the branches. A quantity d becomes meaningful only in an enlarged theory containing a bulk, mediator, shared boundary data, or another interaction geometry.

The pair-exchange involution is defined minimally by

$$\mathcal{C}_{\text{pair}}: \quad U_+ \leftrightarrow U_-, \qquad \eta_B \mapsto -\eta_B. \tag{8}$$

It does not assert that the full state is an exact C, CP, T, or CPT image. In particular, this construction differs from a CPT-reflected pre-Big-Bang branch [11]; both branches here may advance toward their own futures. It also differs from adjacent matter and antimatter domains inside one connected observable universe, whose annihilating boundaries are strongly constrained [9].

3 Common seed and pair-neutral source

Let Σ_i be a neutral common seed, interpreted as a boundary condition or parent state rather than as a classically traversable region. Define the extensive charge covariantly on a branch hypersurface $\Sigma_{i,r}$ by

$$\mathcal{Q}_{i,r} = \int_{\Sigma_{i,r}} J_B^\mu \, \mathrm{d}\Sigma_\mu, \tag{9}$$

where J_B^μ may be replaced by a model-specific $B-L$-like current. A pair-odd source $\mathcal{S}_i(\lambda)$ is postulated:

$$\frac{\mathrm{d}\mathcal{Q}_{i,r}}{\mathrm{d}\lambda} = r\,\mathcal{S}_i(\lambda), \qquad \mathcal{Q}_{i,r}(\lambda_0) = 0. \tag{10}$$

Hence

$$\mathcal{Q}_{i,r}(\lambda) = r \int_{\lambda_0}^{\lambda} \mathcal{S}_i(\lambda')\,\mathrm{d}\lambda', \qquad \mathcal{Q}_{i,+} + \mathcal{Q}_{i,-} = 0. \tag{11}$$

Equation (11) is the fundamental balance condition. Intensive ratios such as η_B cannot generally be added across unequal photon numbers or volumes. Equal magnitudes $\eta_{B,+} = -\eta_{B,-}$ follow only in the symmetric limit with corresponding normalization. The seed source and the later causal separation are also independent assumptions: the sign flip does not cause separation, and separation does not generate the sign flip.

A microscopic completion must explain the source, the magnitude of b, and the implementation of the Sakharov conditions. Equation (10) is therefore an ansatz, not a baryogenesis calculation. Moreover, interpreting the seed as a process that changes a disconnected topology would invoke nontrivial classical-gravity restrictions [17]. A safer minimal reading is that $\mathcal{M}_+$ and $\mathcal{M}_-$ are jointly specified by a common boundary condition.

4 Within-branch annihilation and residuals

Using proper time t_r within branch r, take the Boltzmann system

$$\dot{n}_{B,r} + 3H_r n_{B,r} = S_{B,r} - R_r, \tag{12}$$
$$\dot{n}_{\bar{B},r} + 3H_r n_{\bar{B},r} = S_{\bar{B},r} - R_r, \tag{13}$$

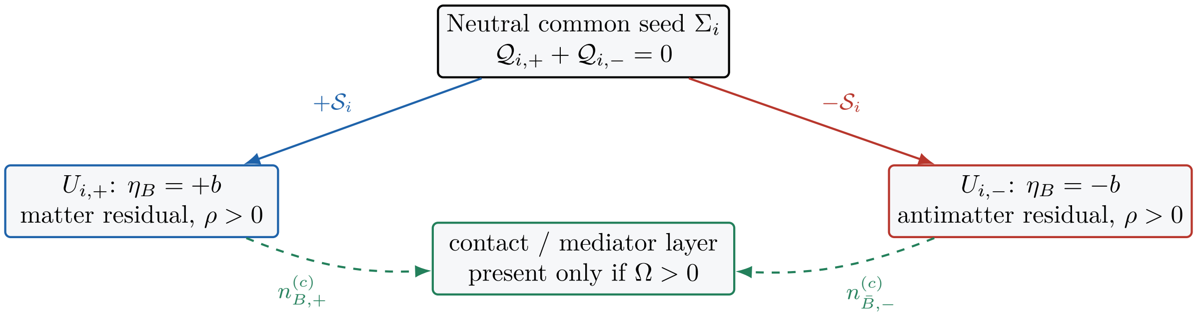

Figure 1: Logical architecture. The common seed correlates opposite extensive charges. It is not a later communication channel. Cross-branch annihilation requires a separately specified contact or mediator layer and vanishes identically in the strict-separation model.

with

$$R_r = \langle \sigma_{\rm ann} v_{\rm rel} \rangle_r \left(n_{B,r} n_{\bar{B},r} - n^{\rm eq}_{B,r} n^{\rm eq}_{\bar{B},r} \right). \tag{14}$$

Subtracting Eqs. (12) and (13) cancels the symmetric reaction term:

$$\frac{\mathrm{d}}{\mathrm{d}t_r} \left[a_r^3 (n_{B,r} - n_{\bar{B},r}) \right] = a_r^3 (S_{B,r} - S_{\bar{B},r}). \tag{15}$$

After the asymmetry source freezes out, the comoving difference $\Delta N_r = a_r^3 (n_{B,r} - n_{\bar{B},r})$ is conserved in this approximation. Efficient annihilation reduces the sum but cannot remove the unmatched number, leaving

$$N_{{\rm res},r} = |\Delta N_r|, \qquad n_{{\rm res},r} \simeq |\eta_{B,r}| n_{\gamma,r}. \tag{16}$$

Asymmetric freeze-out equations of this type are standard in particle-cosmology applications [12]. The $+$ branch retains baryons, while the $-$ branch retains antibaryons. In both, the annihilated symmetric component is converted to radiation and other positive-energy products. The phrase "the universe survives" therefore means that an unmatched material component remains; spacetime itself is not a subtractive residue.

5 Portal-regulated cross-branch annihilation

5.1 Master rate and interaction layer

The phenomenological master equation requested for the pair is

$$\boxed{\Gamma_{+-} = \Omega(d) \langle \sigma v \rangle n_+ n_-.} \tag{17}$$

Its precise branch-resolved form is

$$\Gamma^{\rm fwd}_{+-}(\lambda) = \Omega[d(\lambda)] \, \langle \sigma_{\rm ann} v_{\rm rel} \rangle_c \, n^{(c)}_{B,+}(\lambda) n^{(c)}_{\bar{B},-}(\lambda), \tag{18}$$

where $0 \le \Omega \le 1$. The superscript (c) is essential: densities defined on separate manifolds cannot simply be multiplied. A bulk, mediator, shared boundary, or overlap map must first represent both incident populations in one effective contact three-volume V_c. The usual factor $\langle \sigma v \rangle n_+ n_-$ has dimensions volume^{-1} time^{-1}; therefore Γ_{+-} is an event-rate density per contact proper time.

Let τ_c be contact proper time and $\kappa_c = \mathrm{d}\tau_c / \mathrm{d}\lambda > 0$. Detailed balance gives

$$\Gamma^{\rm net}_{+-} = \Gamma^{\rm fwd}_{+-} - \Gamma^{\rm rev}_{+-}, \qquad \mathcal{A}_{+-}(\lambda) \equiv \frac{\mathrm{d}N^{\rm net}_{\rm ann}}{\mathrm{d}\lambda} = \kappa_c V_c \Gamma^{\rm net}_{+-}. \tag{19}$$

The reverse term is negligible only in a sufficiently cold, dilute final state. In the strict model, no contact clock or volume exists; Eqs. (18) and (19) are then understood by their unique zero extension, $\Omega = \Gamma_{+-} = \mathcal{A}_{+-} = 0$.

The factor $\Omega(d)$ is not derived from the standard annihilation cross section. It is a new overlap or portal hypothesis. In a common extra-dimensional geometry, localized wavefunctions can produce exponentially suppressed overlaps [13], suggesting illustrative forms such as $\Omega \propto \exp(-2d/\ell)$. Braneworld models supply possible bulk and brane language [14], but no particular realization is assumed here.

Table 2: Three mutually distinct portal regimes. A nonzero Ω means that the *full* theory contains a causal interaction channel even if the induced branch geometries remain spatially separate.

Model	Portal condition	Causal meaning	Leading consequence
Strict separation	$\Omega = 0$ identically	Disjoint components; no exchange of particles, energy, or information	$\Gamma_{+-} = 0$; partner has no direct signal
Weak portal	$0 < \Omega \ll 1$	A suppressed mediator or overlap exists in the full theory	Small depletion only if integrated optical depth is also $\ll 1$
Transient contact	$\Omega > 0$ only during a bounded interval	Temporary common interaction layer, for example near a bounce or brane collision	Finite burst of annihilation, radiation, and possibly gravitational waves

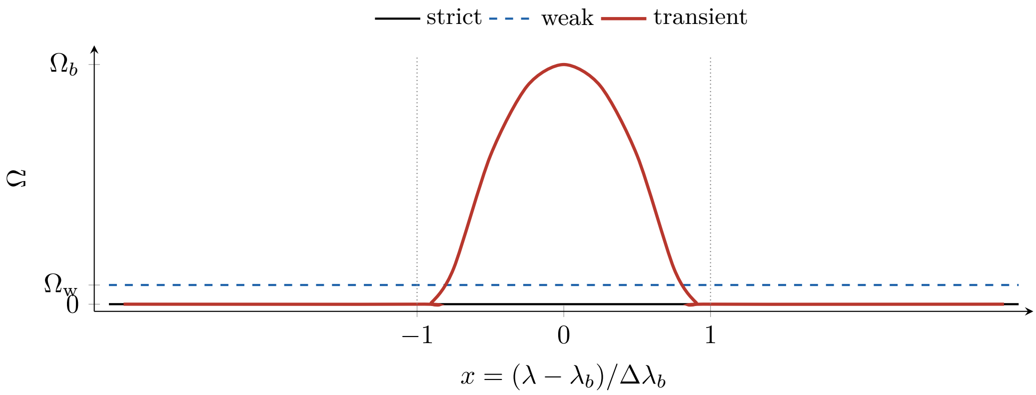

Figure 2: Portal histories. The three curves denote alternative models, not simultaneous conditions. The compact transient pulse is exactly zero outside the contact interval.

5.2 Three causal regimes

The following alternatives remove the apparent contradiction between "never connected" and "able to annihilate."

For strict separation,

$$\Omega(\lambda) \equiv 0 \quad \Longrightarrow \quad \Gamma_{+-}(\lambda) = 0. \tag{20}$$

Opposite asymmetries are inherited from the seed and are not maintained by communication. One should not replace Eq. (20) by $d \to \infty$, because d need not exist on a disjoint union.

For a weak portal,

$$0 < \Omega(\lambda) \ll 1. \tag{21}$$

Instantaneous smallness is insufficient to guarantee survival over a long duration; the integrated exposure must also be small. For the matter population,

$$\mathcal{T}_+ = \int \mathrm{d}\tau_c \, \Omega \langle \sigma_{\mathrm{ann}} v_{\mathrm{rel}} \rangle_c n^{(c)}_{\bar{B},-}, \qquad P_+ = \exp(-\mathcal{T}_+). \tag{22}$$

The controlled weak-depletion regime is $\mathcal{T}_+ \ll 1$, for which $\Delta n_+/n_+ \simeq -\mathcal{T}_+$.

For transient contact, choose a compact pulse centered at λ_b:

$$\Omega(\lambda) = \Omega_b W\left(\frac{\lambda - \lambda_b}{\Delta\lambda_b}\right), \quad W(x) = \begin{cases} \exp\left(1 - \dfrac{1}{1 - x^2}\right), & |x| < 1, \\ 0, & |x| \geq 1. \end{cases} \tag{23}$$

Thus $\Omega > 0$ only for $|\lambda - \lambda_b| < \Delta\lambda_b$. Such a layer could be an effective description of brane approach or collision in a larger spacetime [15, 16]. It should not be described simultaneously as exact disconnection.

5.3 Finite exposure and depletion bound

If expansion is negligible during a short contact and the two incident densities are equal, the simplified equation

$$\frac{\mathrm{d}n}{\mathrm{d}\tau_c} = -\Omega\langle\sigma v\rangle n^2 \tag{24}$$

integrates to

$$n_f = \frac{n_i}{1 + n_i\mathcal{K}}, \qquad \mathcal{K} = \int_{\tau_a}^{\tau_b} \Omega\langle\sigma v\rangle \,\mathrm{d}\tau_c. \tag{25}$$

A finite interval therefore need not annihilate the full residual. Particle counting also imposes

$$N_{\mathrm{ann}}^{\mathrm{net}} \le \min\Big(N_{B,+}^{\mathrm{in}}, N_{\bar{B},-}^{\mathrm{in}}\Big). \tag{26}$$

Equations (22)–(26) make the intuitive "amount of mixing" quantitative.

6 Causality, energy, and entropy

6.1 Causal completion

Any nonzero Ω requires a causal microscopic completion. A mediator field should have a retarded kernel in the full geometry; Eq. (18) is then the homogeneous Markovian limit after mediator propagation and memory have been coarse grained. Otherwise the equation would amount to instantaneous action between disconnected manifolds. Consequently, "causally disconnected" is exact only for $\Omega = 0$; "portal separated" and "transiently connected" are the accurate descriptions of the other two regimes.

6.2 Energy conversion

Let $\bar{E}_{B,+} > 0$ and $\bar{E}_{\bar{B},-} > 0$ be the incident mean energies. For the net event number in Eq. (19), introduce a contact/radiation sector C:

$$\left(\frac{\mathrm{d}E_+}{\mathrm{d}\lambda}\right)_{\mathrm{int}} = -\bar{E}_{B,+}\mathcal{A}_{+-}, \tag{27}$$

$$\left(\frac{\mathrm{d}E_-}{\mathrm{d}\lambda}\right)_{\mathrm{int}} = -\bar{E}_{\bar{B},-}\mathcal{A}_{+-}, \tag{28}$$

$$\frac{\mathrm{d}E_C}{\mathrm{d}\lambda} = (\bar{E}_{B,+} + \bar{E}_{\bar{B},-})\mathcal{A}_{+-}. \tag{29}$$

It follows that

$$\frac{\mathrm{d}}{\mathrm{d}\lambda}(E_+ + E_- + E_C)\bigg|_{\mathrm{int}} = 0. \tag{30}$$

In the cold equal-mass limit, the power density delivered to products is

$$q_{\mathrm{ann}} \simeq 2m_B c^2 \Gamma_{+-}^{\mathrm{net}}. \tag{31}$$

The factor $2m_Bc^2$ is only the nonrelativistic approximation; kinetic energy and final-state masses must be included when relevant.

Equations (29) and (30) are a phenomenological subsystem ledger of the type used in Paper V [5]. They do not assert that every curved spacetime possesses a unique global scalar energy. In an expanding control volume, the covariant stress-energy equation also supplies work and flux terms, including the familiar $p\,\mathrm{d}V$ contribution.

6.3 Coarse-grained entropy

To avoid confusing entropy flow with the annihilation symbol Γ_{+-}, write

$$\frac{\mathrm{d}S_i}{\mathrm{d}\lambda} = \Pi_i + \sum_j \Phi_{j\to i}^{(S)}, \qquad \Phi_{i\to j}^{(S)} = -\Phi_{j\to i}^{(S)}. \tag{32}$$

For forward and reverse reaction rates in the contact layer, a standard nonnegative coarse-grained production term is

$$\Pi_{\text{ann}} = k_B \kappa_c V_c (\Gamma_{+-}^{\text{fwd}} - \Gamma_{+-}^{\text{rev}}) \ln\left(\frac{\Gamma_{+-}^{\text{fwd}}}{\Gamma_{+-}^{\text{rev}}}\right) \geq 0, \tag{33}$$

because $(x - y)\ln(x/y) \geq 0$ for positive x and y. Summing Eq. (32) over a closed ensemble cancels antisymmetric exchange currents and gives $\mathrm{d}S_{\text{tot}}/\mathrm{d}\lambda = \sum_i \Pi_i \geq 0$. Energy closure therefore does not imply thermodynamic reversibility.

7 Embedding in cyclic cosmology

Let n label an ordered sequence of cycles. The signed branch asymmetries are written

$$\eta_{B,n,r} = r b_n, \qquad b_n > 0. \tag{34}$$

The branch label r is distinct from the drift sign s_d used below. A minimal memory-and-drift map adapted from Paper II [2] is

$$\epsilon_{n+1} = q\epsilon_n, \qquad \chi_{n+1} = \chi_n + \nu\epsilon_n, \qquad b_{n+1} = b_n(1 + s_d\kappa\epsilon_n), \tag{35}$$

with $0 < q < 1$, $s_d = \pm 1$, and $1 + s_d\kappa\epsilon_n > 0$. A CP-even macroscopic quantity must depend on the magnitude b, not on a fractional power of negative η_B:

$$Q_{n,r} = Q_{0,r} \exp[\gamma_Q(\chi_{n,r} - \chi_{0,r})] \left(\frac{b_n}{b_0}\right)^{\delta_Q}. \tag{36}$$

For weak memory,

$$\ln \frac{Q_{n+1,r}}{Q_{n,r}} = \Xi_Q \epsilon_n + O(\epsilon_n^2), \qquad \Xi_Q = \gamma_Q \nu + \delta_Q s_d \kappa. \tag{37}$$

The classifier of Paper II is retained, but it acts on $b = |\eta_B|$. In the exact conjugate limit, CP-even expansion histories agree; differences require unequal entropies, asymmetric portal losses, CP-odd corrections, or other branch-dependent data. The portal factor may also acquire a cycle index, but its map cannot be inferred from Eq. (35) without a microscopic contact model.

8 Phenomenology and falsifiability

8.1 Strict model

For $\Omega = 0$, the partner branch produces no direct signal in ours. The statements "an inaccessible partner exists" and "no partner exists" are observationally indistinguishable within this baseline. It is therefore a logical consistency model, not an empirically established cosmology. Its only nontrivial content is the joint boundary condition and the absence of forbidden cross-branch transfer.

8.2 Portal models

When $\Omega > 0$, the measurable control parameter is integrated exposure rather than instantaneous overlap alone. Potential consequences are:

1. **Baryon depletion.** Contact before or during nucleosynthesis can alter the baryon abundance and light-element yields; the observed baryon density and standard BBN agreement constrain such loss [7, 8].
2. **Radiation injection.** Equation (31) can modify relativistic energy density, ionization, CMB anisotropies, or spectral distortions, depending on epoch and final states.
3. **Diffuse high-energy products.** Late products entering our branch can contribute photons or secondary particles. The usual matter-antimatter domain constraints do not apply to $\Omega = 0$, but become relevant when a portal creates an effective boundary or transports products [9].
4. **Expansion-history change.** Converting nonrelativistic rest energy to radiation changes the equation of state and hence $H(a)$.

5. **Gravitational waves.** A sufficiently inhomogeneous brane collision or bounce may create a burst or stochastic background. The rate law alone does not determine its spectrum.

A convenient dimensionless injection diagnostic is

$$\epsilon_{\rm inj} \equiv \frac{q_{\rm ann}}{H\rho_{\rm tot}}, \tag{38}$$

with consistent units and epoch-dependent densities. A specified portal model is falsified if its minimum predicted Ω and duration necessarily imply excessive depletion, radiation injection, or an excluded expansion history. Conversely, an anomalous radiation or gravitational-wave signal would not uniquely establish a conjugate universe; a convincing test requires correlated predictions from a microscopic portal.

9 Discussion and limitations

The framework resolves the main logical tension by separating three layers of causation. The common seed accounts phenomenologically for correlated opposite charges. Ordinary kinetics inside each branch accounts for the residual majority. A distinct portal or contact geometry accounts for any later cross-branch annihilation. None of these statements alone derives either of the other two.

Several limitations remain. The seed source is postulated, so the model does not derive the value of b or its sign correlation from a Lagrangian. The distance d, overlap Ω, common density map, mediator spectrum, and annihilation cross section must be derived in a microscopic completion. A topology-changing contact is especially nontrivial in classical general relativity [17]; a pair of branes that already share a bulk is a cleaner transient realization. The ensemble energy is coarse grained rather than a universal generally covariant global charge. Antimatter nucleosynthesis, recombination, structure formation, and compact-object evolution are not calculated here.

The terminology also sets hard boundaries on the claim. "Negative branch" means negative signed baryon excess, never negative mass, negative energy, or negative temperature. "Separate" means distinct spacetime components or sectors, not different dimensionalities. "Annihilation" means conversion of particle rest energy, not disappearance of the full universe. Even if strong contact removes both residual material populations, the products in Eq. (29) remain and continue to gravitate.

10 Conclusion

A neutral common seed can be represented phenomenologically as producing two universe branches with opposite extensive baryon asymmetry, $\eta_{B,+} = +b$ and $\eta_{B,-} = -b$. Within each branch, symmetric annihilation preserves the comoving difference and leaves a matter or antimatter residual of magnitude $|N_B - N_{\bar{B}}|$. Both branches contain positive energy and can share the same CP-even gravitational evolution.

The central interaction law,

$$\Gamma_{+-} = \Omega(d)\langle\sigma v\rangle n_+ n_-,$$

supports three logically distinct models: strict separation with $\Omega = 0$, a weak portal with $0 < \Omega \ll 1$ and small integrated optical depth, and transient contact with $\Omega > 0$ only near a bounce or collision. Once Ω is nonzero, the full theory is not strictly causally disconnected, even when its two induced $3+1$ dimensional branches remain spatially separate.

Annihilation transfers positive matter energy into a contact/radiation sector, preserving the effective ensemble energy ledger and producing nonnegative coarse-grained entropy. Replacing signed η_B by $b = |\eta_B|$ in CP-even cyclic observables also extends the companion cyclic model without negative densities or complex fractional powers. The strict model establishes consistency but has no direct cross-branch observable. The next scientific step is therefore a finite, causal portal derived from a microscopic action and confronted with baryon abundance, BBN, CMB, high-energy-background, expansion-history, and gravitational-wave bounds.

References

[1] Y. Tsuno, "Light-Chronometric Convergence Cosmology: Finite Light-Track Age from a State-Dependent Effective Causal Speed," companion manuscript (2026).

[2] Y. Tsuno, "Geometric and Causal Drift in Cyclic Cosmology: A Phenomenological Classification from Extra Spatial Freedom, Baryon Asymmetry, and Memory," companion manuscript (2026).

[3] Y. Tsuno, "Chronometric Geometry in Cyclic Cosmology: Extra Spatial Freedom and an Infinite Sequence of Cycles," companion manuscript (2026).

[4] Y. Tsuno, "Operational Freeze-Out of Causal Propagation in an Effective Black-Hole Core: A Toy Model Beyond Classical Geometric Validity," companion manuscript (2026).

[5] Y. Tsuno, "Multiverse Balance Laws in Cyclic Cosmology: An Open-Subsystem Formulation for Energy and Entropy Exchange," companion manuscript (2026).

[6] A. D. Sakharov, "Violation of CP Invariance, C Asymmetry, and Baryon Asymmetry of the Universe," *JETP Letters* **5**, 24–27 (1967); reprinted in *Physics-Uspekhi* **34**, 392–393 (1991), doi:10.1070/PU1991v034n05ABEH002497.

[7] N. Aghanim et al. (Planck Collaboration), "Planck 2018 Results. VI. Cosmological Parameters," *Astronomy & Astrophysics* **641**, A6 (2020), doi:10.1051/0004-6361/201833910, arXiv:1807.06209.

[8] B. D. Fields, K. A. Olive, T.-H. Yeh, and C. Young, "Big-Bang Nucleosynthesis after Planck," *Journal of Cosmology and Astroparticle Physics* **03**, 010 (2020), doi:10.1088/1475-7516/2020/03/010, arXiv:1912.01132.

[9] A. G. Cohen, A. De Rujula, and S. L. Glashow, "A Matter-Antimatter Universe?," *Astrophysical Journal* **495**, 539–549 (1998), doi:10.1086/305328, arXiv:astro-ph/9707087.

[10] E. K. Anderson et al. (ALPHA Collaboration), "Observation of the Effect of Gravity on the Motion of Antimatter," *Nature* **621**, 716–722 (2023), doi:10.1038/s41586-023-06527-1.

[11] L. Boyle, K. Finn, and N. Turok, "CPT-Symmetric Universe," *Physical Review Letters* **121**, 251301 (2018), doi:10.1103/PhysRevLett.121.251301, arXiv:1803.08928.

[12] H. Iminniyaz, M. Drees, and X. Chen, "Relic Abundance of Asymmetric Dark Matter," *Journal of Cosmology and Astroparticle Physics* **07**, 003 (2011), doi:10.1088/1475-7516/2011/07/003, arXiv:1104.5548.

[13] N. Arkani-Hamed and M. Schmaltz, "Hierarchies without Symmetries from Extra Dimensions," *Physical Review D* **61**, 033005 (2000), doi:10.1103/PhysRevD.61.033005, arXiv:hep-ph/9903417.

[14] L. Randall and R. Sundrum, "An Alternative to Compactification," *Physical Review Letters* **83**, 4690–4693 (1999), doi:10.1103/PhysRevLett.83.4690, arXiv:hep-th/9906064.

[15] J. Khoury, B. A. Ovrut, P. J. Steinhardt, and N. Turok, "The Ekpyrotic Universe: Colliding Branes and the Origin of the Hot Big Bang," *Physical Review D* **64**, 123522 (2001), doi:10.1103/PhysRevD.64.123522, arXiv:hep-th/0103239.

[16] P. J. Steinhardt and N. Turok, "A Cyclic Model of the Universe," *Science* **296**, 1436–1439 (2002), doi:10.1126/science.1070462, arXiv:hep-th/0111030.

[17] R. Geroch, "Topology in General Relativity," *Journal of Mathematical Physics* **8**, 782–786 (1967), doi:10.1063/1.1705276.