

## ENTROPIC SUCTION THEORY v2

### Working Paper WP-Annihilation

*Matter-Antimatter Annihilation as Complete Vortex Geometric Cancellation*

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*WORKING PAPER — Physical picture established. Quantitative derivation of annihilation timescales pending substrate field equations.*

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*STATUS: Working paper. No new axioms. No free parameters. The annihilation mechanism follows directly from the vortex substrate picture established in EST v2 V34 and WP-ElectronBleed (June 2, 2026). Experimental confirmation in superfluid and BEC systems cited. Protonium included as a second test case.*

### Abstract

Matter-antimatter annihilation is identified in Entropic Suction Theory v2 as the complete geometric cancellation of two matched counter-rotating vortex structures in the substrate. Annihilation requires three conditions to be met simultaneously: equal vortex size, equal vortex frequency, and opposite rotation direction. Equal mass is a consequence of the first two conditions, not a separate requirement. When all three conditions are met, the two structures fully interpenetrate and cancel everywhere simultaneously. The energy stored in both structures releases into the substrate as photons — vortex rings shed as the structures unwind.

This mechanism is directly confirmed by experimental observations of vortex-antivortex annihilation in superfluid helium and Bose-Einstein condensates, where counter-rotating matched vortex pairs attract, approach, and cancel completely with energy converting to sound pulses. Co-rotating pairs of the same size do not annihilate — they orbit each other stably. The geometry requirement is absolute.

Two cases are examined: electron-positron annihilation and proton-antiproton annihilation (protonium). In both cases the annihilation timescale is identified as the orbital decay time — the time for the orbit of the attracting pair to shrink from initial capture radius to full vortex overlap. This is a derivable quantity from vortex dynamics once substrate field equations are available.

The proton-electron system is shown to be incapable of annihilation despite opposite charge, because the vortex geometries are mismatched by a factor of 1836 in mass and approximately 440 in vortex radius. The neutron lock is an asymmetric stable configuration, not a near-annihilation event.

# 1. The Geometric Conditions for Annihilation

## 1.1 What Annihilation Is

In EST v2, all matter is structured substrate. Every particle is a vortex configuration in the substrate medium. Energy is stored in the vortex geometry. Mass is the energy of that geometry divided by  $c^2$  —  $E = mc^2$  as identity, not conversion.

Annihilation is not a special process requiring a new mechanism. It is the simplest possible outcome when two vortex structures of opposite rotation meet: they cancel. The substrate disturbance created by one is exactly undone by the other. The medium returns to its undisturbed state. The energy that was stored in both structures has nowhere left to be stored in structured form — it releases as photons, which are the substrate's natural propagating disturbance mode.

## 1.2 The Three Required Conditions

For complete cancellation to occur, three geometric conditions must be satisfied simultaneously:

- Equal vortex size: the spatial extent of both structures must match. If one vortex is larger than the other, the overlap is incomplete. The larger structure's outer regions have no counterpart to cancel against. Partial overlap produces partial cancellation of the overlap region and leaves a residual structure — not annihilation.
- Equal vortex frequency: the internal oscillation rate of both structures must match. Frequency determines energy per unit volume of the vortex. Mismatched frequencies mean mismatched energy densities. The cancellation is not uniform and the structures do not fully cancel.
- Opposite rotation direction: the two structures must be counter-rotating. Co-rotating vortices of the same size and frequency do not cancel — they orbit each other or merge. Only opposite rotation produces the destructive superposition that drives the substrate back to equilibrium.

Equal mass is not a fourth independent condition. It follows automatically from equal size and equal frequency. If two vortex structures have the same spatial geometry and the same internal frequency, they store the same energy. Since mass IS energy in EST v2, they have the same mass. The mass equality observed in particle-antiparticle pairs is a consequence of the geometric matching, not a separately imposed rule.

## 1.3 Why the Attraction is Immediate

Two counter-rotating vortex structures in a fluid medium attract each other. This is not a special force — it is a direct consequence of the flow fields they create. Each vortex drives substrate flow in a pattern that carries the other vortex toward it. The moment two counter-rotating matched vortices come within range of each other's flow fields, they begin moving toward each other.

There is no delay on the attraction. The force is immediate and continuous from the moment of range overlap. This is confirmed in superfluid experiments where vortex-antivortex pairs are observed to approach each other from the moment of creation.

However, attraction and annihilation are not the same event. Attraction brings the vortices together. Annihilation requires complete geometric overlap. The timescale of annihilation is determined by the approach dynamics — how quickly the vortices can achieve full interpenetration given their orbital motion, their approach velocity, and the substrate resistance to rapid structural change.

## **1.4 Why Annihilation Requires Complete Overlap**

The cancellation mechanism is point-by-point superposition of opposite substrate disturbances. At every point in space where the two vortex structures overlap, the opposite rotations cancel the local substrate pressure deviation. The medium at that point returns to equilibrium.

For the cancellation to be complete — for both structures to disappear entirely — every point of one structure must be co-located with the corresponding opposite point of the other. This requires full geometric interpenetration. Partial overlap produces partial annihilation of the overlapping region only, leaving residual structure.

This is why annihilation is all-or-nothing in the geometric sense. Either the structures achieve full overlap and cancel completely, or they do not fully overlap and some residual structured energy remains. There is no stable half-annihilated state.

Note: in practice, quantum fluctuations in the substrate mean that the overlap condition is met probabilistically rather than at a precise instant. This is the physical origin of the decay probability picture in standard quantum mechanics — it is not fundamental randomness but the statistics of a threshold process in a fluctuating medium.

## **2. Experimental Confirmation in Physical Fluid Systems**

### **2.1 Vortex-Antivortex Annihilation in Superfluids and BECs**

The annihilation mechanism proposed here is not a theoretical extrapolation. It is directly observed in physical superfluid systems at laboratory scales. Counter-rotating quantized vortex pairs in Bose-Einstein condensates and superfluid helium have been studied experimentally and theoretically in detail.

The observed behavior matches the EST v2 picture exactly:

- Counter-rotating vortex pairs of matched size attract each other and approach until they annihilate completely. Their kinetic energy converts entirely to sound pulses — compressible waves in the medium. This is the superfluid analog of gamma ray emission in electron-positron annihilation.

- Co-rotating vortex pairs of the same size do not annihilate. They orbit each other in stable circular paths. The same rotation direction produces no cancellation tendency — the flow fields reinforce rather than cancel.
- The annihilation is deterministic and repeatable. It is not random. Given matched counter-rotating vortices at a known separation, the annihilation proceeds along a predictable trajectory.
- The energy conversion is complete. All incompressible kinetic energy stored in both vortex structures converts to compressible wave energy (sound) upon annihilation. No residual vortex structure remains.

These observations in physical superfluid systems provide direct experimental grounding for the EST v2 annihilation mechanism. The substrate is finer than atomic superfluids and the length and energy scales are different, but the vortex cancellation geometry is the same physics.

## **2.2 The Sound Pulse and the Gamma Ray**

In superfluid vortex annihilation, the energy releases as a sound pulse — a compressible pressure wave propagating through the medium. In electron-positron annihilation, the energy releases as two gamma ray photons propagating in opposite directions.

In EST v2 these are the same physical event at different scales. The sound pulse in the superfluid is a pressure wave in the atomic medium. The gamma ray photon is a vortex ring — a discrete structured pressure disturbance — propagating through the substrate medium.

The two-photon requirement in electron-positron annihilation — why two gamma rays and not one — is a momentum conservation constraint. Two photons emitted in opposite directions carry zero net momentum, matching the zero net momentum of the annihilating pair at rest. One photon cannot satisfy momentum conservation. This is geometry, not a special rule.

The energy of each photon — 511 keV, the electron rest mass energy — is exactly half the total energy of the annihilating pair. The energy splits equally between the two photons because the two counter-rotating vortices are geometrically identical. Each contributes equally to the energy released.

## **3. Electron-Positron Annihilation**

### **3.1 Why the Positron is the True Antimatter Electron**

The positron has identical mass to the electron — same vortex size, same vortex frequency. It has opposite charge — opposite rotation direction. It satisfies all three geometric conditions for complete cancellation with the electron.

In EST v2 charge is the rotational spin direction of the vortex. Positive charge is one rotation direction. Negative charge is the opposite. The positron is the electron with its

rotation reversed. Same geometry, opposite handedness. This is what antimatter means in EST v2: the same vortex structure with opposite rotation.

### 3.2 The Annihilation Sequence

The physical sequence for electron-positron annihilation:

- Electron and positron come within range of each other's vortex flow fields. Immediate mutual attraction begins — opposite rotation creates attractive substrate flow.
- If both particles are free, they spiral toward each other. If one or both are bound (positronium — the electron-positron atom), the bound orbit decays as the system bleeds energy into the substrate.
- The orbit shrinks. At some point the two vortex structures begin to spatially overlap. As overlap increases, partial cancellation begins — the overlapping regions cancel and energy begins releasing as photons.
- Full overlap is achieved. Complete cancellation occurs everywhere simultaneously. Both structures vanish. Two 511 keV gamma ray photons are emitted in opposite directions carrying the total rest mass energy of both particles.

The annihilation is not instantaneous from initial contact. It requires the orbit to decay to the overlap scale. For positronium, the measured lifetime — on the order of nanoseconds to microseconds depending on spin state — is the orbital decay time. This is a derivable quantity from vortex dynamics and substrate bleed rate.

### 3.3 Spin State Dependence — Para and Ortho Positronium

Positronium exists in two spin states. Para-positronium (singlet state, spins antiparallel) decays in approximately 125 picoseconds producing two gamma rays.

Ortho-positronium (triplet state, spins parallel) decays in approximately 142 nanoseconds producing three gamma rays.

In EST v2 terms: the spin state determines the rotational alignment of the two vortex structures as they approach. Antiparallel spins (para) means the rotation axes are aligned for direct cancellation — the vortices approach in the optimal geometry for complete overlap. The decay is fast.

Parallel spins (ortho) means the rotation axes are not optimally aligned. The vortices cannot achieve direct head-on overlap — the geometry requires a more complex approach trajectory. The decay is slower and requires three photons to satisfy both energy and momentum conservation given the non-head-on geometry of the annihilation.

The factor of approximately 1000 difference in lifetime between para and ortho positronium is a geometric consequence of vortex approach trajectory, not a quantum selection rule imposed from outside. Quantitative derivation requires substrate field equations.

## 4. Protonium — Proton-Antiproton Annihilation

### 4.1 What Protonium Is

Protonium is a hydrogen-like bound state in which a proton and an antiproton orbit each other. The antiproton has identical mass to the proton — same vortex size  $r_p = 0.879 \times 10^{-15} \text{ m}$ , same vortex frequency  $\omega_p = c/r_p = 3.411 \times 10^{23} \text{ s}^{-1}$ . It has opposite charge — opposite rotation direction. It is the proton's true antimatter counterpart.

Protonium has been produced and studied experimentally at CERN's LEAR facility and at the Antiproton Decelerator. The proton and antiproton form a bound orbit and annihilate on a timescale of microseconds, producing a spray of pions and gamma rays.

### 4.2 Why the Attraction is Immediate but Annihilation Takes Microseconds

The proton and antiproton attract immediately upon coming within range. Opposite rotation direction creates attractive substrate flow between them — same mechanism as electron-positron attraction and same mechanism as the proton-electron attraction in hydrogen.

But the annihilation takes microseconds, not an instant. The reason is orbital mechanics combined with the overlap requirement.

When the proton and antiproton are captured into a bound state, they are orbiting at a separation much larger than the vortex overlap scale. The vortex radius of the proton is  $r_p = 0.879 \times 10^{-15} \text{ m}$ . The initial orbital radius of protonium is on the order of the Bohr radius — approximately  $10^{-10} \text{ m}$ , which is 100,000 times larger than  $r_p$ .

The orbit must decay from  $10^{-10} \text{ m}$  down to the vortex overlap scale of approximately  $r_p$  before annihilation can occur. That decay proceeds by the system bleeding orbital energy into the substrate — the same bleed mechanism that governs all energy loss in EST v2. The microsecond timescale is the time for this orbital decay.

The picture in sequence:

- Proton and antiproton captured into orbit at large separation. Immediate mutual attraction. Orbit begins decaying as energy bleeds into substrate.
- Orbit shrinks continuously. Both structures remain intact — they are too far apart to overlap. The decay is gradual.
- Orbit reaches the vortex overlap scale. The two proton-scale vortex structures begin to spatially interpenetrate. Partial cancellation begins. Energy begins releasing rapidly.
- Full overlap achieved. Complete cancellation. Annihilation products — pions and gamma rays — carry away the total rest mass energy of both particles ( $2 \times 938 \text{ MeV} = 1876 \text{ MeV}$ ).

### 4.3 Why Pions Are Produced

Electron-positron annihilation produces only photons — vortex rings propagating through the substrate. Proton-antiproton annihilation produces pions in addition to photons. In EST v2 terms this is a scale effect.

The proton vortex is far more energetic and compact than the electron vortex. When two proton-scale vortex structures cancel at  $r_p$  scale, the energy release per unit volume is enormous. The substrate cannot absorb all of that energy as simple propagating vortex rings (photons) — the local energy density exceeds the threshold for nucleon-scale vortex ring formation. Pions are intermediate-scale vortex structures that form transiently as the energy cascades from proton scale down to photon scale.

This is a physical picture, not a calculation. The quantitative threshold for pion production versus direct photon production requires substrate field equations. What EST v2 identifies is the mechanism: the annihilation energy cascade produces intermediate structured objects when the local energy density exceeds nucleon-scale vortex formation thresholds.

#### **4.4 The Substrate Energy Cascade — Pions as Turbulent Intermediates**

The pion picture has a direct analog in classical fluid dynamics. When a violent energy release occurs in a fluid — a cavitation bubble collapsing, a high-speed impact — the fluid does not absorb the energy in a single step. The energy cascades through a hierarchy of intermediate vortex structures. Large vortices shed smaller vortices, which shed smaller ones still, all the way down to the dissipation scale where the energy finally becomes heat. Each scale in the cascade is a transient intermediate structure that exists briefly and then breaks down further. This is the Kolmogorov energy cascade. Richardson stated it plainly: big whirls have little whirls that feed on their velocity, and little whirls have lesser whirls, and so on to viscosity.

Proton-antiproton annihilation is exactly this situation in the substrate. Two proton-scale vortex structures cancel simultaneously. The energy release per unit volume at  $r_p$  scale is enormous. The substrate cannot jump directly from proton-scale structures to photon-scale vortex rings — the energy density gap is too large. It cascades. Pions are the first step down — intermediate vortex structures at roughly  $1/7$  the proton energy scale. They are not stable resonance configurations. They are cascade intermediates, exactly analogous to the intermediate vortices in classical turbulent flow. The neutral pion decaying in 84 attoseconds into two gamma rays is the bottom of the cascade — the energy finally reaching photon-scale vortex rings the substrate can carry stably. The charged pions decaying in 26 nanoseconds into muons and neutrinos represent an intermediate step that has not yet reached the photon floor.

This picture has a significant implication. The full particle physics zoo of mesons, kaons, and short-lived hadrons produced in high-energy collisions may be the EST v2 turbulent cascade spectrum — the complete set of intermediate vortex scales the substrate passes through when absorbing energy releases at nucleon scale and above. Each particle corresponds to a specific transient scale in the cascade. Its mass encodes its position in the cascade hierarchy. Its lifetime encodes how quickly that scale breaks down further. The Standard Model classifies these particles by quark content and

quantum numbers. EST v2 identifies them as turbulence — mathematically classifiable but physically generated by a single substrate cascade mechanism.

The cascade spectrum prediction — that particle masses should follow a geometric series corresponding to the substrate vortex scale hierarchy — is a falsifiable consequence of this picture. Recorded as Open Problem 24.

## 5. Why the Proton and Electron Cannot Annihilate

### 5.1 The Geometric Mismatch

The proton and electron have opposite charge — opposite rotation direction. They attract each other. But they cannot annihilate because their vortex geometries are completely mismatched:

- Vortex radius:  $r_p = 0.879 \times 10^{-15} \text{ m}$  vs  $r_e = 3.862 \times 10^{-13} \text{ m}$ . The electron vortex is approximately 440 times larger than the proton vortex.
- Vortex frequency:  $\omega_p = 3.411 \times 10^{23} \text{ s}^{-1}$  vs  $\omega_e = 7.76 \times 10^{20} \text{ s}^{-1}$ . The proton spins approximately 440 times faster than the electron.
- Mass:  $m_p = 1.673 \times 10^{-27} \text{ kg}$  vs  $m_e = 9.109 \times 10^{-31} \text{ kg}$ . Mass ratio 1836 — a direct consequence of the geometric mismatch.

For annihilation the two vortices would need to achieve complete geometric overlap. A proton-scale vortex overlapping with an electron-scale vortex that is 440 times larger cannot achieve complete cancellation. The proton's compact fast vortex would overlap with only a tiny central region of the electron's large diffuse vortex. The vast majority of the electron's vortex structure has no counterpart in the proton to cancel against.

The result would not be annihilation. It would be partial disruption of the overlap region with the remaining electron vortex structure intact. This is not observed because the energy cost of this partial disruption is not favorable — the system finds the lock configuration instead.

### 5.2 The Neutron Lock is Not Near-Annihilation

In the neutron, the proton sits inside the electron's vortex field in a stable lock configuration. The opposite rotation directions create mutual attraction that holds the lock. This might appear to be a step toward annihilation — two opposite-charge vortices in close proximity.

It is not. The neutron lock is a stable asymmetric bound state, not a stalled annihilation. The proton vortex is fully contained inside the electron vortex field but the two structures are not overlapping in the cancellation sense — the proton is a compact tight fast vortex sitting at the center of a large diffuse slow vortex. The geometries are too different to cancel.

What keeps the neutron from annihilating is exactly the geometric mismatch that prevents electron-proton annihilation generally. The lock is stable because the



asymmetry is stable. There is no pathway from the neutron configuration to annihilation without first providing enough energy to match the vortex geometries — which would require converting the electron into a positron (same geometry as electron, opposite rotation) or the proton into an antiproton (same geometry as proton, opposite rotation).

## 6. Summary and Open Problems

### 6.1 The Unified Annihilation Picture

EST v2 identifies matter-antimatter annihilation as complete vortex geometric cancellation. The conditions are:

- Equal vortex size — spatial geometry must match
- Equal vortex frequency — energy density must match
- Opposite rotation — counter-rotating for destructive superposition

Equal mass follows automatically. The energy releases as photons — propagating vortex rings — when the structures cancel. Intermediate products (pions) form when the local energy density at annihilation exceeds nucleon-scale vortex formation thresholds.

Attraction between matter and antimatter is immediate from initial range contact. Annihilation requires complete spatial overlap of the two vortex structures. The annihilation timescale is the orbital decay time — the time for the orbit to shrink from capture radius to vortex overlap scale via substrate bleed.

This picture is confirmed by direct experimental observation of vortex-antivortex annihilation in superfluid and BEC systems, where counter-rotating matched vortex pairs attract, approach, and cancel completely with energy converting to sound pulses.

### 6.2 Open Problems

- OP21 (NEW): Derive the positronium lifetime (para and ortho) from vortex orbital decay rate and substrate bleed. The factor of approximately 1000 between para and ortho lifetimes should follow from the geometric difference in approach trajectory between antiparallel and parallel spin configurations.
- OP22 (NEW): Derive the protonium annihilation timescale from orbital decay rate at proton vortex scale. The microsecond timescale should follow from the ratio of initial capture radius to vortex overlap scale and the substrate bleed rate at proton energies.
- OP23 (NEW): Derive the pion production threshold from substrate field equations. At what local energy density does the annihilation cascade produce intermediate vortex structures rather than direct photon emission?

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*Annihilation is not a special process. It is the simplest outcome when two vortex structures of matched geometry and opposite rotation meet in a substrate medium. The*

*substrate returns to equilibrium. The energy stored in both structures releases into the medium. What standard physics describes with creation and annihilation operators and conservation rules, EST v2 describes with one sentence: two matched counter-rotating vortices in a substrate cancel when they fully overlap.*

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