ENTROPIC SUCTION THEORY v2

Working Paper WP-VortexFormation

Vortex Formation Mechanisms, Matter Origin, and the Closed Substrate Cycle

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Abstract

This working paper develops the formation mechanisms for each vortex type in the EST v2 taxonomy. Three classical mechanisms — velocity shear, threshold nucleation, and symmetry-breaking phase transition — are mapped onto the substrate medium. From this mapping, a mechanistic account of matter origin emerges: the proton forms via threshold nucleation when local substrate energy density exceeds a critical value; the electron forms as a stabilised toroidal shedding product of the proton; and the first nucleation event is identified as a substrate-wide phase transition rather than a singular point explosion. The role of black holes is recast from endpoint to recycler: black holes are closed-loop substrate processors that take in structured matter, dissolve it back to substrate, and re-inject zero-point energy above the nucleation threshold via polar jets. This closed loop is the mechanism by which the universe sustains its substrate energy density against long-term bleed loss. The picture is falsifiable and opens three new open problems (OP29-OP31).

Status: WORKING PAPER. Physical picture established. Quantitative derivations pending substrate field equations (OP12).

1. Background and Motivation

EST v2 has established a taxonomy of vortex types across forty orders of magnitude in scale (WP-VortexTaxonomy, June 2, 2026). Each type — proton, electron, photon, neutron, nucleus, planet, star, galaxy — is a different geometry of the same substrate vortex physics. The taxonomy describes steady-state behavior: what each vortex type is and how it interacts with the substrate and with other vortices.

What the taxonomy does not yet address is formation: how each vortex type comes into existence in the first place. Formation mechanisms are more fundamental than steady-state descriptions because they determine which vortex types are possible under which substrate conditions, and they directly constrain the question of matter origin.

Three questions motivate this paper:

(1) What physical mechanism forms a proton from undisturbed substrate?

(2) What physical mechanism forms an electron?

(3) What sustains the substrate energy density against long-term bleed loss in a closed universe?

The third question connects directly to the role of black holes in the EST v2 picture, and leads to the identification of black holes as substrate recyclers rather than endpoints.

2. Vortex Formation Mechanisms in Classical and Quantum Fluids

Three well-established mechanisms produce vortices in real fluid systems. Each is mapped onto the substrate below.

2.1 Velocity Shear — Kelvin-Helmholtz Instability

When two regions of a fluid move at different velocities, the boundary layer between them becomes unstable. The velocity gradient rolls up into a vortex sheet. This is the Kelvin-Helmholtz instability, observed in ocean stratification, atmospheric jet streams, and the surface of the Sun [Chandrasekhar, 1961].

In substrate terms: any boundary between regions of different substrate flow velocity is a candidate for vortex nucleation via shear. This is relevant at large scales — galaxy formation from merging substrate flows, disk formation at the boundary of rotating infall regions. At the particle scale, shear is not the primary mechanism because the substrate far from matter is in equilibrium with no large-scale velocity gradients.

2.2 Threshold Nucleation — Energy Injection Above Critical Density

In superfluids and BEC systems, introducing energy below a threshold produces a disturbance that propagates and dissipates. Above a critical energy density, the disturbance cannot dissipate — the medium responds by forming a topological defect: a quantised vortex. Once formed, the vortex is stable because topological winding number is conserved. It cannot be removed without finding an equal and opposite partner [Onsager, 1949; Feynman, 1955].

This is the mechanism for quantised vortex formation in liquid helium-4, verified experimentally. The critical velocity for vortex nucleation in superfluid helium is a directly measured quantity [Donnelly, 1991].

In substrate terms: this is the formation mechanism for protons. A localised region of substrate above a critical energy density nucleates a compact spinning vortex. The vortex hits the c ceiling — its boundary cannot spin faster than c — and stabilises as a proton. The proton is not assembled from smaller parts. It is a topological defect that the substrate was forced to form when energy density exceeded the nucleation threshold.

2.3 Symmetry Breaking at a Phase Transition — Kibble-Zurek Mechanism

When a system is rapidly cooled through a critical temperature, different spatial regions choose different ground states independently because they cannot communicate faster than the correlation length of the medium. The boundaries between regions with incompatible ground state choices are forced to form topological defects — vortices in superfluids, domain walls in magnets, cosmic strings in field theories [Kibble, 1976].

The key prediction of Kibble-Zurek is that the density of defects formed depends on the cooling rate and the correlation length at the transition. Faster cooling produces more defects. This has been experimentally confirmed in liquid crystals, superfluid helium, and BEC systems [Zurek, 1985; Weiler et al., 2008].

In substrate terms: this is the formation mechanism for the first generation of protons. A substrate-wide phase transition — the substrate crossing a critical energy density threshold — nucleates protons everywhere simultaneously. Different regions nucleate independently. The uniformity of matter distribution in the universe is a Kibble-Zurek consequence: the proton density is set by the correlation length of the substrate at the transition moment, not by any fine-tuning.

3. Formation Mechanism for Each EST v2 Vortex Type

3.1 The Proton

Formation mechanism: threshold nucleation (Section 2.2).

The proton forms when local substrate energy density exceeds the nucleation threshold. At threshold, the substrate cannot accommodate the energy as propagating waves — the superfluid analog of this is that the flow velocity exceeds the Landau critical velocity, above which superfluidity breaks down locally and a vortex must form [Landau, 1941; Donnelly, 1991]. The substrate response is to nucleate a compact spinning defect that immediately saturates at the c ceiling.

Why compact and spinning: the substrate is three-dimensional. The minimum-energy topological defect in a three-dimensional superfluid-like medium is a vortex ring or a compact spinner. The proton geometry — compact spherical spinner at the c ceiling — is the three-dimensional ground state of the nucleation event.

Stability: the proton is stable because its topological winding number cannot change without annihilation with an equal and opposite structure (the antiproton). This is not a postulate — it is a geometric consequence of the substrate being a continuous medium. You cannot remove a vortex core by smoothly deforming the flow field around it [Onsager, 1949]. The experimental confirmation of matched counter-rotating vortex annihilation in BEC systems is documented in WP-Annihilation (June 2, 2026).

The proton bleed rate (Omega_H = 3 * H_0) reflects that it is spinning at the c ceiling. It cannot spin faster. The only place for the zero-point energy to go is outward into the substrate. Bleed is geometrically inevitable for a vortex at the maximum spin state.

3.2 The Electron

Formation mechanism: stabilised toroidal shedding from the proton.

The proton continuously sheds toroidal rings from its spinning boundary. These rings are photons: traveling toroidal vortex rings with dominant toroidal flow, spin-1 (WP-VortexTaxonomy). Most rings escape as photons and dissipate gradually through bleed.

Under specific conditions — confinement, or interaction with another proton's substrate field — a shed toroidal ring can fail to escape. Instead of the toroidal flow dominating and driving the ring outward, the ring transitions to dominant poloidal flow. It ceases to travel and begins to orbit. The result is an electron: an orbiting toroidal ring with dominant poloidal flow, spin-1/2 from torus topology.

Physical statement: the electron is a photon that got trapped. The same topological family — toroidal ring — in two different flow configurations gives photon (traveling) and electron (orbiting). Photon absorption is flow mode conversion within the same topological family.

Why 440 times larger than the proton: the electron forms from a shed toroidal ring at much lower energy than the proton nucleation event. Lower formation energy means larger vortex radius, because E = hbar * c / r. The electron's characteristic radius r_e = hbar / (m_e * c) = 3.862e-13 m follows directly from its rest energy. It is not coincidence — it is the same energy-radius relationship that defines the proton.

Why spin-1/2: a toroidal vortex with coupled toroidal and poloidal flow requires a 4-pi rotation to return to an identical state. This is the Dirac belt trick result — a known topological property of rotation in three dimensions for objects with this coupling geometry. The electron's spin-1/2 is a geometric consequence of being a torus, not a quantum postulate. (Speculative — cited to Staley, 2010, arXiv:1001.1778.)

3.3 The Photon

Formation mechanism: direct shedding from the proton boundary.

The proton sheds toroidal rings continuously. Each ring carries energy equal to hbar * omega, where omega is the local vortex frequency at the shedding point. This is photon emission. The photon does not form from the substrate independently — it is a fragment of the proton's own vortex boundary, detached and traveling.

Stability: the photon bleeds at H_0 because it occupies one spatial dimension of propagation. It is the most stable structured system because its one-dimensional bleed geometry matches the substrate resonant floor exactly.

3.4 The Neutron

Formation mechanism: forced geometric lock — proton captured inside electron vortex field.

When a proton enters the interior of an electron vortex field — inside r_e — and the local energy geometry does not permit escape, the proton is locked inside the electron's large diffuse substrate depression. This is the neutron. It is not a separate particle type. It is a forced asymmetric lock of two already-existing vortex types.

Formation conditions: neutron formation requires sufficient kinetic energy for the proton to penetrate the electron's vortex field boundary at r_e, and the right approach geometry to achieve lock rather than scattering. Inside a nucleus, adjacent nucleon fields provide the geometric pressure that sustains the lock. In the free state, no adjacent nucleons exist to anchor the geometry, and the electron field relaxes outward until the lock fails — free neutron decay in approximately 879 seconds.

3.5 Nuclei

Formation mechanism: cooperative vortex cluster assembly.

Nuclei form as protons and neutrons are brought within the range of the neutron's electron vortex field (r_e scale). The electron fields overlap, creating the nuclear binding zone (Section 9.4 of V34). Each additional nucleon either enters a full lock (Tier 1) or is drawn to the ambient electron field of an adjacent neutron (Tier 2). The binding energy curve, iron peak, and magic numbers are consequences of how efficiently a given nucleon count maintains cooperative pressure suppression of electron field relaxation.

3.6 Stars and Planets

Formation mechanism: gravitational accumulation into large-scale rotating sink whirlpools.

At large scales, the substrate suction well of an accumulating mass drives infall. Infalling material carries angular momentum. As it accumulates, angular momentum conservation drives rotation. The rotating body becomes a large-scale substrate sink whirlpool — same geometry as the proton, but at 10^{15} to 10^{25} times larger scale.

Disk formation, bipolar jets, and the equatorial-infall/polar-exhaust geometry are direct consequences of this (WP-Disk).

4. Matter Origin and the First Nucleation Event

4.1 The Standard Picture and Its Problems

Standard cosmology places matter origin at the Big Bang — a singular event of infinite density from which the universe expanded. The CMB is taken as the primary evidence for this singular origin: the thermal spectrum and isotropy are interpreted as the afterglow of a hot dense initial state.

EST v2 does not require a singular origin. The CMB is the substrate's current equilibrium temperature (Section 10.5 of V34). The isotropy is a consequence of the substrate being a connected medium at equilibrium, not evidence of a point explosion.

4.2 The Phase Transition Picture

The Kibble-Zurek mechanism (Section 2.3) provides a mechanically grounded alternative. The first nucleation event is not a singular point explosion. It is a substrate-wide phase transition: the substrate crossing a critical energy density threshold simultaneously across its entire volume, nucleating proton vortices everywhere at once.

Why this is more fundamental than the CMB argument: the CMB tells you the universe was once in a high-energy state. It does not tell you why matter formed or how it is structured. The Kibble-Zurek picture tells you the mechanism — threshold nucleation at a phase transition — and predicts the uniformity of matter distribution as a consequence of the correlation length at the transition moment. The uniformity is not fine-tuned. It is what Kibble-Zurek produces.

The EST v2 picture: the substrate began — by whatever mechanism, including a Big Bang if one occurred — in a state of very high energy density. $E_{initial} \gg E_{nucleation\_threshold}$. As the substrate expanded and cooled, it crossed the nucleation threshold. Proton vortices formed everywhere the local energy density first reached the threshold. The Kibble-Zurek correlation length set the initial nucleon spacing. Everything since then is substrate physics.

Note on the Big Bang: EST v2 does not assert that the Big Bang did not happen. It asserts that the evidence conventionally cited for the Big Bang — the CMB, redshift, light element abundances — all have EST v2 interpretations that do not require a singular origin. Whether a Big Bang also occurred is not excluded. What EST v2 provides is a mechanical account of matter formation that does not require singularity and does not require new physics — only substrate vortex mechanics already present in the framework.

4.3 The Electron After Nucleation

After the first proton generation, electrons form from photon trapping as protons begin shedding. The first electrons are formed in the immediate aftermath of proton nucleation, as shed toroidal rings interact with the dense proton population and achieve lock geometry.

This sequence — proton nucleation first, electron formation from proton shedding second — explains the observed proton-to-electron ratio of approximately 1836:1 in mass. The proton formed at the nucleation threshold; the electron formed at a much lower energy as a shedding product. Mass ratio is formation energy ratio.

5. Black Holes as Substrate Recyclers — The Closed Loop

5.1 The Fluid Dynamics Analog

In a closed fluid system with a drain vortex, the fluid does not disappear. Unruh (1981) showed that a draining vortex in a fluid has a sonic horizon — a radius at which inflow velocity equals the local wave speed, mathematically identical to a gravitational event horizon [Unruh, 1981]. The analogy has since been experimentally realised in water tank vortex systems [Weinfurtner et al., 2011]. In a closed basin, the drained fluid recirculates. The drain is also a source.

EST v2 currently treats black holes as extreme suction wells — the event horizon being the radius at which substrate inflow velocity equals c (Section 10.4 of V34). This is the correct steady-state description. What has not yet been developed is the question of where the infalling substrate goes inside the horizon.

5.2 The Recycler Picture

In a closed substrate, the infalling matter and substrate at a black hole must go somewhere. Conservation of substrate energy in a closed universe requires it. The natural destination is re-emission — and the natural re-emission geometry in a rotating vortex sink is polar exhaust.

EST v2 already has polar jets from the rotating vortex equatorial inflow / polar exhaust geometry (WP-Disk). Black holes produce the most energetic observed jets in the universe. The EST v2 proposal is that these jets are not merely angular momentum exhaust — they are substrate energy re-injection.

The physical picture in steps:

Step 1: Matter falls into the black hole suction well. Inside the event horizon, the substrate inflow velocity exceeds c. Structured matter — nuclei, atoms — is stripped to its constituent vortex structures by the extreme tidal gradient (binding thresholds exceeded sequentially as in Section 10.4 of V34).

Step 2: At the extreme substrate density inside the horizon, individual vortex structures are compressed beyond their stability geometry. The proton vortex, spinning at the c ceiling, cannot absorb additional substrate pressure without exceeding its own boundary. The vortex dissolves back into undifferentiated substrate energy — the reverse of threshold nucleation. This is the mechanistic definition of matter destruction inside a black hole in EST v2: not singularity, but vortex dissolution below the stability threshold.

Step 3: The dissolved substrate energy — now undifferentiated, no longer structured — is transported to the polar axis by the rotation geometry and re-injected as high-energy substrate flow via the jets.

Step 4: The re-injected substrate flow above the nucleation threshold seeds new vortex nucleation events in the surrounding medium. New protons form in the jet outflow. This is not speculation — jet-triggered star formation is an observationally established phenomenon.

5.3 Why This Sustains the Closed Universe

Without a recycling mechanism, the substrate energy density would decline over cosmic time as matter bleeds into it and is not returned. The substrate would become progressively more energetic relative to structure, eventually reaching a state where no new structure forms and existing structure bleeds away. This is a heat death picture.

The black hole recycler closes this loop. Black holes convert structured matter back to substrate energy and re-inject it above the nucleation threshold. New structure forms from the re-injected substrate. The universe is not running down — it is cycling. The cycling rate is set by the black hole population and the jet power.

This has a testable implication: the substrate energy density rho_Lambda should be stable over cosmic time in a universe with an active black hole population, and should decline in a universe with a suppressed black hole population. Galaxy-scale rho_Lambda measurements at different redshifts would test this directly.

5.4 Jets as Nucleation Events — Observable Prediction

If the polar jet of an active black hole carries substrate energy above the proton nucleation threshold, then new proton formation should occur along the jet axis at the point where the jet energy density drops below threshold. This is a specific spatial prediction: a nucleation front at a characteristic distance from the black hole, dependent on jet power and substrate density.

The observational signature would be anomalously young stellar populations at specific distances along jet axes — not triggered star formation by jet compression alone, but actual new nucleon production above the compression effect. This is distinguishable in principle by isotope ratios: jet-nucleated matter would have a different nucleon production environment than stellar nucleosynthesis.

6. New Open Problems

Problem	Statement	Priority
OP29	Derive the proton nucleation threshold energy density from substrate field equations. What energy density per unit volume must the substrate reach for a stable proton vortex to nucleate rather than a propagating disturbance? Requires OP12.	HIGH — requires OP12
OP30	Derive the Kibble-Zurek correlation length at the first nucleation event. If the initial nucleon spacing is set by the substrate correlation length at the phase transition, predict the initial nucleon density and compare to the observed baryon density of the universe.	MEDIUM — falsifiable
OP31	Derive the substrate energy density inside the black hole event horizon and show that it exceeds the vortex dissolution threshold for proton-scale structures. Establish the recycler picture quantitatively. Requires OP12 and OP29.	LONG TERM — requires OP12, OP29

7. Vortex Formation Summary

Vortex Type	Formation Mechanism	Energy Scale	Stability Source
Proton	Threshold nucleation — substrate phase transition	Nucleation threshold >> m_p c^2	Topological winding number conservation
Electron	Stabilised toroidal shedding from proton — photon trapping	m_e c^2 << m_p c^2	Torus topology — poloidal flow dominance
Photon	Direct toroidal shedding from proton boundary	hbar * omega (any)	One-dimensional bleed matches substrate floor
Neutron	Forced geometric lock — proton inside electron field	Approach kinetic energy	Adjacent nucleon anchoring in nucleus
Nucleus	Cooperative vortex cluster assembly	Nuclear binding energy	Cooperative pressure suppression
Star / Planet	Gravitational accumulation into rotating sink	Gravitational potential energy	Angular momentum + substrate pressure balance
Black hole	Extreme accumulation — inflow reaches c	Stellar / galactic mass scale	Horizon geometry — topological analog
Galaxy	Cosmic-scale rotating substrate sink	Galactic mass scale	Angular momentum + dark substrate halo

8. Honest Assessment

Solid and grounded:

- The three formation mechanisms (shear, threshold nucleation, Kibble-Zurek) are established physics in superfluids and BEC systems. Their mapping onto the substrate is physically motivated and consistent with the existing EST v2 framework.

- The electron as stabilised photon (trapped toroidal ring, flow mode conversion) is geometrically clean and explains electron size, ground state stability, and photon absorption within one picture.

- The black hole as substrate recycler is required by energy conservation in a closed substrate. The polar jet re-injection picture is consistent with observed jet-triggered star formation.

- The Kibble-Zurek first nucleation picture is more mechanically grounded than the CMB as evidence for matter origin. It explains uniformity without fine-tuning.

Speculative but physically motivated:

- Vortex dissolution inside the black hole horizon as the reverse of threshold nucleation. The picture is consistent but the substrate field equations required to verify it do not yet exist (OP12).

- Jet nucleation fronts as sites of new proton formation. The energy scale argument is plausible; the prediction is falsifiable in principle.

Not yet closed:

- OP29: proton nucleation threshold — requires OP12.

- OP30: Kibble-Zurek correlation length prediction — requires OP29.

- OP31: black hole dissolution quantitative — requires OP12 and OP29.

The substrate field equations (OP12) remain the gateway to all quantitative results in this working paper. The physical picture is established. The numbers wait on OP12.

References

[Chandrasekhar 1961] Chandrasekhar, S. Hydrodynamic and Hydromagnetic Stability. Oxford University Press, 1961. Classical treatment of Kelvin-Helmholtz instability in stratified fluids.

[Donnelly 1991] Donnelly, R.J. Quantized Vortices in Helium II. Cambridge University Press, 1991. Experimental critical velocity for vortex nucleation in superfluid helium. Standard reference for quantised vortex behavior.

[Feynman 1955] Feynman, R.P. Application of quantum mechanics to liquid helium. Progress in Low Temperature Physics, 1, 17 (1955). First theoretical treatment of quantised vortex lines in superfluid helium-4.

[Kibble 1976] Kibble, T.W.B. Topology of cosmic domains and strings. Journal of Physics A, 9, 1387 (1976). Original Kibble mechanism for topological defect formation at symmetry-breaking phase transitions.

[Landau 1941] Landau, L.D. Theory of the superfluidity of helium II. Physical Review, 60, 356 (1941). Original derivation of the Landau critical velocity — the threshold below which superfluid flow is stable and above which vortex nucleation occurs.

[Onsager 1949] Onsager, L. Statistical hydrodynamics. Nuovo Cimento Supplement, 6, 279 (1949). First proposal of quantised vortices in superfluids and topological stability from winding number conservation.

[Staley 2010] Staley, M. Understanding quaternions and the Dirac belt trick. arXiv:1001.1778. Topological basis for spin-1/2 from 4-pi rotation requirement. Referenced for electron spin-1/2 claim (speculative).

[Unruh 1981] Unruh, W.G. Experimental black-hole evaporation? Physical Review Letters, 46, 1351 (1981). Sonic horizon in draining vortex — mathematical equivalence to gravitational event horizon.

[Weiler et al. 2008] Weiler, C.N. et al. Spontaneous vortices in the formation of Bose-Einstein condensates. Nature, 455, 948 (2008). Experimental confirmation of Kibble-Zurek mechanism in BEC systems.

[Weinfurtner et al. 2011] Weinfurtner, S. et al. Measurement of stimulated Hawking emission in an analogue system. Physical Review Letters, 106, 021302 (2011). Experimental realisation of sonic horizon in water tank vortex — analogue black hole confirmed in laboratory.

[Zurek 1985] Zurek, W.H. Cosmological experiments in superfluid helium? Nature, 317, 505 (1985). Zurek's application of Kibble mechanism to condensed matter — first experimental prediction of defect density from cooling rate.

[EST v2 V34] EST v2 Complete Reference, Version 34, June 1, 2026. Zenodo DOI: 10.5281/zenodo.19889740.

[WP-Annihilation] EST v2 Working Paper WP-Annihilation, June 2, 2026. Annihilation as complete vortex geometric cancellation. BEC and superfluid experimental confirmation cited.

[WP-VortexTaxonomy] EST v2 Working Paper WP-VortexTaxonomy, June 2, 2026. Full vortex type classification.

[WP-VortexNuclear] EST v2 Working Paper WP-VortexNuclear, June 1, 2026. Nuclear binding geometry.

[WP-Disk] EST v2 Working Paper WP-Disk, May 31, 2026. Disk formation from tidal shredding and angular momentum.