Hydrodynamic Electromagnetism

Maxwell's Equations in an Effective, Inviscid Medium (Non-Viscous Ether Analogy)

A Reformulation of Classical Electrodynamics under the
Hydrodynamic Quantum Gravity Paradigm

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Abstract

Status: Preprint (not peer reviewed).
This paper proposes an effective-medium interpretation of classical electromagnetism within the broader Hydrodynamic Quantum Gravity programme. The aim is not to claim experimental confirmation of a literal mechanical ether, but to present a coherent mapping in which vacuum electromagnetism is described as dynamics of an inviscid effective medium (an "ether" only in the historical, analogue sense) consistent with the standard Maxwell structure.

The manuscript addresses common objections historically raised against medium-based interpretations—most notably the existence of transverse polarisation, Lorentz invariance, the observed value of the fine-structure constant, and the accuracy of quantum electrodynamics—by outlining specific mechanisms or correspondence claims and clearly distinguishing what is derived within the proposed mapping from what remains conjectural or out of scope.

This reformulation does not attempt to replace Quantum Electrodynamics (QED) as a calculation framework. Rather, it offers a candidate physical ontology compatible with an effective-field description: a translation table is provided between hydrodynamic variables (pressure, vorticity, phase) and electromagnetic quantities (E, B, charge, current), with proposed tests and explicit open questions identified throughout.

Scope note: Sections on fine-structure constant derivations, QED interpretation, and broader unification claims are presented as hypotheses and discussion, not as established results; the core contribution of this preprint is the explicit mapping of Maxwell's equations into a hydrodynamic form and the identification of discriminating, falsifiable implications.

1. Introduction: Motivation and Scope

1.1 Maxwell's Abandoned Vision

James Clerk Maxwell did not conceive of electromagnetic fields as abstract mathematical entities. His original treatise employed mechanical models—gears, vortices, idle wheels—to describe the physical processes underlying electrical and magnetic phenomena. Maxwell believed empty space exhibited medium-like properties:

'We can scarcely avoid the inference that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena.'

The 20th century stripped this physical interpretation. Relativity seemed to forbid a detectable medium; quantum mechanics abstracted fields into probability amplitudes. What remained were Maxwell's equations—extraordinarily successful but ontologically hollow. We could calculate what fields do without understanding what fields are.

This paper restores Maxwell's vision with modern physics. The medium he intuited exists—not as rigid luminiferous ether, but as a non-viscous ether: empty space whose dynamic properties are mathematically identical to those of a quantum superfluid. The mechanical models he sketched were crude approximations of hydrodynamic reality.

Scope & limits: This preprint proposes an effective mapping and interpretive ontology for classical electromagnetism. It does not claim experimental confirmation of a vacuum medium, does not derive QED from first principles, and does not claim to compute the fine-structure constant as an established result. Where correspondences depend on assumptions, they are stated explicitly; where claims are speculative extensions, they are labeled as such.

1.2 Motivation: Interpretational Tensions

Contemporary electromagnetic theory faces foundational problems that suggest incomplete understanding. The term 'electricity' has no single clear definition—it conflates charge, current, energy, and field into a confused amalgam. Students learn contradictory explanations: electricity flows in loops yet is consumed by devices; electrons carry energy yet energy travels in fields; current moves slowly yet signals propagate at light speed. These are not pedagogical failures but symptoms of missing ontology.

Deeper mysteries persist: Why is charge quantised? Why does $\alpha \approx 1/137$? Why do magnetic monopoles not exist? Why does the electron's point-charge model yield infinite self-energy? Standard theory accepts these as brute facts. This framework derives them as geometric necessities of a superfluid substrate.

1.3 The Effective-Medium Hypothesis

A critical clarification is necessary at the outset. This framework does not propose that space contains a substance. Space is genuinely empty—it contains no particles, no lattice, no material substrate. However, empty space demonstrably possesses dynamic properties: it permits movement, carries energy, supports wave propagation, exhibits vacuum fluctuations measurable via the Casimir effect and the Lamb shift. These are not the properties of 'nothing.' They are the properties of a medium—specifically, properties mathematically identical to those of a superfluid.

The term *non-viscous ether* captures this ontological status with precision. 'Ether' because space has properties and supports dynamics; 'non-viscous' because there is no drag, no resistance, no detectable substance. This is why Michelson and Morley found nothing: there is no substance to detect motion through. Yet the mathematics of superfluids correctly describes vacuum dynamics because space exhibits the same behavioural properties—zero viscosity, wave propagation, topological defects, emergent Lorentz invariance.

Hydrodynamic Electromagnetism proposes that the vacuum belongs to the same universality class as superfluid Helium-3A (^{3}He-A)—a chiral superfluid whose low-energy excitations obey equations identical to the Standard Model. This identification, developed extensively by Volovik [1], is not metaphor but mathematical isomorphism.

Two foundational axioms constrain the framework:

Axiom 1 (Relative Motion). There is no experimentally accessible absolute reference frame within the medium for internal observers. While the substrate may possess an ontological rest frame, this frame remains hidden from any entity composed of the medium's own excitations.

Axiom 2 (Trapped Oscillation). Oscillation is the fundamental mechanism for trapping energy into stable configurations. Matter is not a static defect but a dynamic, self-sustaining resonance—an oscillon maintained by the ponderomotive balance between internal radiation pressure and external vacuum elasticity.

From these axioms, we derive electromagnetism as the acoustics and vorticity of the non-viscous ether.

2. The Nature of the Medium

2.1 The Effective, Inviscid Medium (Analogy)

Unlike the rigid 'luminiferous ether' of the 19th century, the non-viscous ether possesses specific physical properties derived from quantum condensate physics:

Zero Viscosity. Below the Landau critical velocity, excitations (matter) move through the vacuum without friction. This resolves Le Sage's fatal objection to push-gravity theories—there is no drag because there is no dissipation in superfluid flow.

Thermodynamic Equilibrium. The vacuum possesses enormous microscopic energy density, but this energy does not gravitate. According to the Gibbs–Duhem relation for a self-sustained condensate at equilibrium [1], the immense microscopic energy is exactly cancelled by the chemical potential term: $P_{vac} = -\varepsilon_{vac} + \mu n = 0$. Electromagnetic phenomena arise not from this equilibrium energy but from local pressure *gradients*—departures from equilibrium created by the presence of charged oscillons.

Quantum Coherence. The vacuum is described by a single macroscopic wavefunction $\Psi = \sqrt{n} \exp(i\theta)$, where n is the condensate density and θ is the phase. This coherence underlies both gauge invariance and the quantisation of vorticity.

Chiral Superfluid Character. The vacuum belongs to the ^{3}He-A universality class—a chiral superfluid with topologically protected Fermi points. This specific structure, characterised by a complex order parameter encoding orientation, chirality, and superfluid phase, permits transverse wave modes and emergent Lorentz invariance.

2.2 Emergent Lorentz Invariance

If empty space behaves like a physical medium, why does the Michelson–Morley experiment detect no motion through it? The answer lies in Fermi point topology.

Near a Fermi point, the energy spectrum of quasiparticles takes the form:

$$E^2 = c^2_s(p - eA)^2$$

This is mathematically identical to the relativistic dispersion relation for a massless Weyl fermion. Because all matter and measuring instruments are composed of these quasiparticles, all physical interactions are governed by the 'acoustic metric' of the medium. An observer moving through the non-viscous ether experiences length contraction and time dilation physically—atomic structure deforms against the medium's elastic properties—such that the speed of sound c_s always appears isotropic.

Lorentz invariance is not fundamental symmetry of empty space but emergent symmetry of the quasiparticle spectrum. The absolute rest frame may exist ontologically but remains operationally inaccessible to internal observers. This is Axiom 1 realised through Fermi point topology.

3. Electrostatics as Pressure Gradients

3.1 The Electric Field Redefined

In the hydrodynamic framework, the electric field E is identified as the pressure gradient in the non-viscous ether:

$$E \equiv -\nabla P / \rho q$$

where P is the local vacuum pressure, ρ is the fluid density, and q is a coupling constant relating pressure to electric units.

A 'charge' is a localised topological defect in the vacuum, maintained by self-sustaining oscillation (Axiom 2). The oscillon's internal vibration creates a pressure differential with the surrounding vacuum. A positive charge corresponds to a localised high-pressure zone (source); a negative charge to a localised low-pressure zone (sink).

This immediately explains why electric field lines emanate from positive charges and terminate on negative charges—they trace the pressure gradient from high to low, exactly as flow lines in fluid dynamics.

3.2 Coulomb's Law from the Bjerknes Force

In 1906, Vilhelm Bjerknes [2] investigated the forces between pulsating bodies in a fluid. He derived that two spheres oscillating at frequency ω in an incompressible fluid exert a mutual force—the Secondary Bjerknes Force—through acoustic radiation pressure.

The mechanism: Sphere 1 pulsates, creating a pressure wave. This wave reaches Sphere 2, which is also pulsating. Depending on the phase relationship, the spheres gain or lose energy from each other's pressure field. The time-averaged force between two oscillons with volume pulsation rates $\dot{\tilde{V}}_1$ and $\dot{\tilde{V}}_2$ is:

$$\langle F^1 \rangle = -(\rho / 4\pi r^2)\ \langle \dot{\tilde{V}}_1 \dot{\tilde{V}}_2 \rangle$$

This derivation provides physical ontology for the inverse-square law: it is a geometric consequence of spherical wave spreading in three-dimensional space. The energy of the pressure wave spreads over surface area $4\pi r^2$, leading naturally to $1/r^2$ force dependence.

3.3 Charge: Topology and Phase

The Bjerknes force explains attraction and repulsion through phase coherence, but charge itself has a deeper origin: topology.

Charge quantisation arises from topology. In a superfluid condensate, the velocity field is the gradient of phase angle: $v_s = (\hbar/m)\nabla\theta$. For the wavefunction to be single-valued, the phase change around any closed loop must be an integer multiple of 2π. Circulation—and thus vorticity flux—is quantised in discrete units. If electric charge corresponds to the topological winding number of the oscillon defect, then charge must be quantised. The discrete nature of particle charges reflects the discrete nature of topology.

Charge sign is described by the Bjerknes phase relationship. In-phase oscillation ($\varphi = 0$) produces attraction; out-of-phase oscillation ($\varphi = \pi$) produces repulsion. 'Positive' and 'negative' are not substances but phase modes of the oscillon's vibration relative to the background zero-point field. Like charges repel because they oscillate in the same phase mode; unlike charges attract because they are in complementary (opposite) phase modes.

These two aspects are complementary, not identical. Topology determines *what* charge values are possible (integer winding numbers); phase determines *how* charges interact (attraction or repulsion). This explains the mysterious fact that positive and negative charges have exactly equal magnitude—they are the same topological structure in opposite phase relationship to the vacuum.

4. Magnetism as Fluid Vorticity

4.1 The Magnetic Field Redefined

The magnetic field *B* is identified as the vorticity Ω of the non-viscous ether:

$$B \equiv \Omega = \nabla \times v_s$$

where v_s is the superfluid velocity field. When a charge (oscillon) moves relative to the vacuum, it creates circulation—a rotational disturbance in the surrounding medium. This circulation is what we measure as a magnetic field.

4.2 Ampère's Law as Circulation Theorem

In classical electromagnetism, Ampère's Law relates magnetic field circulation to electric current. In the hydrodynamic framework, this becomes a statement of Kelvin's Circulation Theorem. Consider circulation Γ around a closed loop C:

$$\Gamma = \oint_C v_s \cdot dl$$

By Stokes' Theorem, this equals the flux of vorticity through the bounded surface S:

$$\Gamma = \int_s (\nabla \times v_s) \cdot dS = \int_s \Omega \cdot dS$$

An electric current (flow of oscillons) induces rotational flow in the surrounding medium. This is the magnetic field. The mathematics of Ampère's Law is preserved; what changes is the physical interpretation.

4.3 The Physical Reality of Field Lines

This interpretation restores physical reality to Faraday's 'lines of force.' In a superfluid, vorticity is constrained to discrete quantised vortex filaments. A magnetic field line is, quite literally, a vortex tube in the vacuum condensate.

The tension and mutual repulsion of magnetic field lines—long treated as mathematical metaphor—become physical tension and hydrodynamic pressure of vortex filaments. This explains why magnetic field lines never terminate (vortex tubes must form closed loops or extend to infinity) and why magnetic monopoles do not exist (you cannot have a vortex tube with only one end).

4.4 Why No Magnetic Monopoles

The non-existence of magnetic monopoles, puzzling in standard theory, becomes geometrically obvious. Vorticity is defined as the curl of velocity:

$$B = \nabla \times v$$

Taking the divergence:

$$\nabla \cdot B = \nabla \cdot (\nabla \times v) = 0$$

The divergence of any curl is identically zero. Magnetic monopoles—sources or sinks of B field—are mathematically impossible in any theory where magnetism is vorticity. This is not an empirical accident but geometric necessity.

5. The Speed of Light as Acoustic Limit

5.1 c as an Effective Wave Speed

Perhaps the most significant paradigm shift is the redefinition of *c*. In Einstein's relativity, *c* is a fundamental constant of geometry. In Hydrodynamic Electromagnetism, *c* is the speed of transverse acoustic modes in the non-viscous ether:

$$c = c_s = \sqrt{(\partial P/\partial \rho)} = \sqrt{(1/\rho \kappa_s)}$$

where P is vacuum pressure, ρ is density, and κ_s is adiabatic compressibility. This identification has profound implications. The 'speed limit' of the universe is not an arbitrary geometric constant but the natural causal limit of the hydrodynamic medium—just as sound speed limits information propagation in air.

5.2 The Permittivity–Permeability Connection

Maxwell's relation $c = 1/\sqrt{(\varepsilon_0\mu_0)}$ becomes physically transparent:

ε_0 (permittivity): The compressibility of the vacuum—how much the medium yields to pressure.

μ_0 (permeability): The density of the vacuum—the inertia of the medium itself.

The formula $c = 1/\sqrt{(\varepsilon_0\mu_0)}$ is the standard acoustic relation for sound speed in an elastic medium. It is not coincidence but identity.

5.3 Local Variation of Effective Wave Speed

If *c* depends on vacuum density and compressibility, then *c* may vary with local conditions. Near massive objects (where the vacuum is stressed by the presence of oscillons), *c* should differ from its value in empty space. This is equivalent to the Shapiro delay already predicted by General Relativity and confirmed experimentally—and corresponds to Puthoff's Polarisable Vacuum representation [4], where gravitational effects are described by a variable refractive index $n(r) = 1 + 2GM/rc^2$.

Whether this local variation has implications at cosmological scales—for instance, whether *c* differed in early cosmological epochs when vacuum conditions may have been different—is a question that lies beyond the scope of this paper. The framework makes no commitment to a specific cosmological model. What it does predict is that any local variation in vacuum properties must produce corresponding variation in the speed of light, consistent with the acoustic interpretation.

6. Addressing Common Objections

Four objections have historically marginalised ether theories. Each finds resolution within the non-viscous ether framework.

6.1 The Polarisation Paradox: Transverse Acoustic Modes

The Objection. Sound waves in fluids are longitudinal (compression waves). Light is transverse (oscillating perpendicular to propagation). If the vacuum is a fluid, how can light be transverse?

The Resolution. The objection assumes a classical fluid. However, the non-viscous ether belongs to the ^{3}He-A universality class—a chiral superfluid whose order parameter is not a scalar but a complex matrix encoding orientation, chirality, and phase. This internal structure provides degrees of freedom absent in classical fluids.

In Fermi systems, the Pauli exclusion principle provides a mechanism for transverse rigidity: occupied quantum states resist deformation of the Fermi surface, creating an effective shear stiffness in the collisionless regime. Landau predicted [5] that this rigidity permits a collective mode—Transverse Zero Sound (TZS)—propagating via Fermi surface deformation rather than local density fluctuation. TZS is a spin-1 vector mode, precisely matching the spin character of the photon. Valentinis, Zaanen, and van der Marel [6] have characterised TZS as a 'material photon' in strongly interacting Fermi systems, reinforcing this identification.

It should be noted that experimental searches for TZS in normal liquid ^{3}He have yielded null results, with attenuation exceeding 2000 cm^{-1} [7]. However, superfluid phases of ^{3}He demonstrably support transverse, polarised acoustic modes. The Acoustic Faraday Effect, observed by Avenel, Varoquaux, and Ebisawa in superfluid ^{3}He-B [8], demonstrates rotation of acoustic polarisation analogous to electromagnetic Faraday rotation—confirming that quantum superfluids possess the internal degrees of freedom necessary for polarised transverse wave propagation. While this specific observation occurs in the B-phase rather than the A-phase, it establishes the principle that quantum superfluids are categorically different from classical fluids in their wave-propagation properties.

Light is identified with transverse acoustic modes of the chiral superfluid vacuum. The 'longitudinal only' objection is invalid for quantum superfluids with complex order parameters.

6.2 The Fine Structure Constant: Wave Closure Derivation

The Objection. The fine structure constant $\alpha \approx 1/137$ characterises electromagnetic interaction strength. Standard physics treats it as a measured value with no derivation. A complete theory must explain this dimensionless constant.

A Promising Direction. Shiva Meucci [9] has calculated α from the wave closure condition of vortex rings in a superfluid. Meucci models the electron not as a point charge but as a stable quantised vortex ring. For such a structure to be stable, the phase of the standing wave constituting the vortex must close constructively around the ring.

Using a fluid-mechanical model with vacuum rigidity parameter, Meucci derives the velocity profile of the vortex field and identifies a 'quantum radius' where the vortex achieves stability. Calculating the phase accumulation Φ at distance $2r_q$ yields:

$$\Phi(2r_e) = -2\pi\alpha$$

This interprets α as a geometric phase factor—the ratio required for the wave to 'bite its own tail' and form a stable particle. The fine structure constant would thus emerge from the closure condition of self-sustaining vortex structures in the non-viscous ether.

This derivation is suggestive but must be treated with appropriate caution. Meucci's calculation awaits peer review and independent verification. If confirmed, it would represent a significant achievement of the hydrodynamic framework—a derivation of a fundamental constant from geometric principles. The result is presented here as a promising direction within the research programme, not as established result.

6.3 QED Precision: Effective Field Theory

The Objection. Quantum Electrodynamics predicts the electron's anomalous magnetic moment to 12 decimal places. How can a hydrodynamic model replicate this without QFT machinery?

The Resolution. The hydrodynamic framework treats QED as an Effective Field Theory. The 'virtual particle loops' of QED are mathematically isomorphic to thermal and quantum fluctuations in the chiral superfluid medium. Volovik [1] demonstrates that perturbation theory in QED is identical to perturbation theory for quasiparticle interactions in ^{3}He-A:

The bare particle is the topological defect (vortex) itself. The dressed particle includes the fluid it drags ('added mass') and scattering from vacuum fluctuations (phonons). For a massless Weyl fermion at a Fermi point, g = 2 exactly. The anomaly (g−2) arises from interaction with high-energy vacuum texture.

Every Feynman diagram has a hydrodynamic analogue. 'Vacuum polarisation' corresponds to local polarisation of the condensate by vortex presence. Because Fermi point topology dominates low-energy behaviour, the expansion series for fluid interactions must match QED series up to the Planck scale.

QED's precision does not refute the non-viscous ether; it confirms that the vacuum behaves as a quantum liquid near a Fermi point. QED is the precise accounting of superfluid fluctuations.

6.4 Gauge Invariance: Phase Symmetry

The Objection. Modern physics is built on gauge symmetries. In a real fluid, velocity and density are physical quantities. How can a 'real' fluid exhibit 'abstract' gauge invariance?

The Resolution. Gauge invariance emerges from phase symmetry of the superfluid wavefunction. A superfluid is described by a complex order parameter:

$$\Psi(r, t) = \sqrt{n}\, exp(i\theta(r, t))$$

The superfluid velocity is proportional to the phase gradient: $v_s = (\hbar/m)\nabla\theta$. Physical density n is invariant under global phase shift $\theta \rightarrow \theta + C$. This is global U(1) symmetry.

Local gauge invariance arises when we consider interaction with the 'effective gauge field' A. In the non-viscous ether framework, the vector potential A corresponds to displacement of the Fermi point in momentum space. A local phase change θ(r) can be compensated by a shift in A, leaving the physical energy spectrum unchanged.

Volovik [1] emphasises that this gauge invariance is emergent and topologically protected. At low energies, quasiparticles (fermions) and collective modes (photons) couple in ways respecting U(1) symmetry because Fermi point topology forbids mass terms that would violate it. Gauge invariance is the mathematical manifestation of phase-coherent quantum condensate hydrodynamics.

7. Charge Quantisation and Conservation

7.1 Quantisation from Topology

Standard physics accepts charge quantisation ($q_e = 1.602 \times 10^{-19}$ C) as empirical fact. The hydrodynamic framework derives it as topological necessity.

In a superfluid condensate, the velocity field is the gradient of phase angle: $v_s = (\hbar/m)\nabla\theta$. For the wavefunction to be single-valued, the phase change around any closed loop must be an integer multiple of 2π:

$$\oint v_s \cdot dl = (\hbar/m)\, 2\pi n = n(h/m)$$

Circulation—and thus vorticity flux—is quantised in discrete units κ = h/m. A vortex cannot have 1.5 windings; it must be an integer. If electric charge corresponds to the topological winding number of the oscillon defect, then charge must be quantised. The discrete nature of particle charges reflects the discrete nature of topology.

7.2 Conservation from Continuity

Charge conservation follows from Kelvin's Circulation Theorem and topological stability. If an electron is a topological knot in the vortex field, it cannot simply untie itself. Topology is preserved under continuous deformation. An electron can only be destroyed by interacting with a knot of opposite topology (positron). The equation of continuity:

$$\partial\rho/\partial t + \nabla \cdot (\rho v) = 0$$

ensures fluid substance is conserved. Applied to the density of topological defects, charge conservation emerges naturally from the persistence of the medium and the mathematical properties of topology.

8. Maxwell's Equations in Hydrodynamic Form

8.1 The Translation Table

Maxwell's equations can be directly translated into statements about superfluid dynamics. The correspondences are summarised in the following table.

Maxwell Term	**Hydrodynamic Equivalent**	**Physical Meaning**
E (Electric Field)	∇P (Pressure Gradient)	Medium pushing on defects
B (Magnetic Field)	$\Omega = \nabla \times v$ (Vorticity)	Rotation of vacuum medium
q (Charge)	Oscillon / Vortex	Stable standing wave
J (Current)	Oscillon flux	Flow of defects
c (Light speed)	c_s (Sound speed)	Transverse acoustic velocity
ε_0 (Permittivity)	κ (Compressibility)	Vacuum elasticity
μ_0 (Permeability)	ρ (Density)	Vacuum inertia

8.2 Gauss's Law for Electricity

$$\nabla \cdot E = \rho/\varepsilon_0$$

Becomes: The divergence of the pressure gradient equals the density of oscillons (charge sources). Pressure gradients emanate from high-pressure (positive) sources and terminate at low-pressure (negative) sinks.

8.3 Gauss's Law for Magnetism

$$\nabla \cdot B = 0$$

Becomes: The divergence of vorticity is zero. Vortex lines have no sources or sinks—they form closed loops. This is a mathematical identity ($\nabla \cdot (\nabla \times v) \equiv 0$), not a contingent fact.

8.4 Faraday's Law

$$\nabla \times E = -\partial B/\partial t$$

Becomes: Changes in vorticity induce pressure gradients. A time-varying rotation of the medium creates compensating pressure adjustments—the electromagnetic induction that drives generators and transformers.

8.5 Ampère–Maxwell Law

$$\nabla \times B = \mu_0 J + \mu_0\varepsilon_0\, \partial E/\partial t$$

Becomes: Circulation (vorticity) is created by current (oscillon flow) and by changing pressure gradients. The displacement current term ($\varepsilon_0\, \partial E/\partial t$) represents the elastic response of the vacuum—pressure changes before bulk flow begins.

8.6 The Wave Equation

Combining Maxwell's equations yields the wave equation:

$$\nabla^2 E = (1/c^2)\, \partial^2 E/\partial t^2$$

This is interpreted as the propagation of transverse acoustic modes through the non-viscous ether. Light is a shear wave in the chiral superfluid vacuum, propagating at the characteristic acoustic velocity of the medium.

9. Connection to Gravity (Companion Framework)

9.1 The Bjerknes Unification

The Bjerknes force provides the key to unifying electromagnetism and gravity. Both emerge from the same mechanism—acoustic radiation pressure between oscillating structures—differing only in phase relationship:

Gravity. All matter oscillates in temporal phase coherence ($\varphi = 0$). The Bjerknes force is always attractive. For gravity to be universally attractive, this phase coherence must be universal—a requirement physically motivated by the natural tendency of coupled oscillator systems to synchronise (the Kuramoto model provides the mathematical framework). However, the mechanism by which approximately 10^{80} particles achieve and maintain this coherence has not been derived from first principles. This phase-locking mechanism remains one of the most significant open problems shared between this paper and the companion gravitational derivation.

Electromagnetism. Charges can oscillate in or out of phase (φ variable). The force can be attractive or repulsive depending on the phase relationship.

Gravity is the degenerate case of electromagnetism where phase freedom is eliminated. The same equation governs both; the physics differs only in the coherence constraint.

9.2 The Hierarchy Problem Dissolved

This framework explains why gravity is 10^{36} times weaker than electromagnetism. Electromagnetism involves direct field interaction at the resonant scale of matter—electron shells, atomic bonds. The coupling is strong because the interaction scale matches the oscillon's characteristic frequency. Gravity involves the residual pressure differential from matter displacing vacuum energy. Since matter represents an infinitesimal displacement of the vacuum's enormous microscopic energy density, the gravitational gradient is correspondingly tiny.

The hierarchy is not fine-tuned but geometrically determined by the ratio of oscillon energy to vacuum energy—like the ratio of a cup of water to the ocean. Gravity is weak because matter is a tiny disturbance in an enormous medium.

10. The Causal Sequence

From the two axioms, phenomena emerge in a specific causal order:

Movement → Pressure → Oscillation → Density → Mass

Relative motion creates pressure gradients (force fields). Self-reinforcing pressure patterns form oscillations. Persistent oscillation creates stable density structure. Trapped oscillation manifests as inertial mass. This sequence is identical to classical acoustics—because the underlying mathematics is the same.

Electromagnetism occupies a specific position within this sequence. The electric field (pressure gradient) and the magnetic field (vorticity) belong to the Pressure stage—they are the force fields created by motion and by the presence of oscillons. Matter (oscillons) occupies the Oscillation → Density → Mass stages. The causal sequence thus provides the logical structure within which both electromagnetism and gravity find their natural place: both are aspects of the Pressure stage, differing in phase constraint, while matter is the Oscillation stage that sources them.

11. Testable Implications (Proposed)

11.1 Predictions Distinguishing HE from Standard Theory

While this framework reproduces all predictions of classical electromagnetism, several areas offer potential distinction:

Vacuum Birefringence. If the vacuum is a chiral superfluid, extreme electromagnetic fields may induce observable polarisation-dependent effects beyond QED predictions.

Local Variation of c. Near massive objects, the speed of light should differ from its value in empty space, consistent with the Shapiro delay and the Polarisable Vacuum representation.

Transverse Mode Detection. Direct detection of transverse acoustic modes with electromagnetic-like polarisation properties in laboratory superfluids would support the identification. The null result for TZS in normal liquid ^{3}He [7] makes this prediction more specific: the modes should be sought in the superfluid phases, where the order parameter provides the necessary internal degrees of freedom.

11.2 Related Experimental Considerations (separate work)

The companion paper ‘Harrison’s Theorem of Anti-gravity’ proposes specific experimental protocols testing the pressure–voltage relationship:

Experiment A: Isolated vacuum chamber monitoring for voltage changes during pumpdown. Experiment C: Correlation of lightning with pressure transients (dP/dt) independent of ice content. Positive results would confirm the pressure–field relationship central to this electromagnetic reformulation.

12. Speculative Applications (Out of Scope)

Theory finds its ultimate validation in practical application. The Hydrodynamic Electromagnetism framework suggests novel approaches to several longstanding engineering challenges.

12.1 Lightning Prediction Systems

If lightning results from pressure-driven voltage spikes rather than ice-crystal charge separation, then high-frequency barometric sensors (dP/dt monitoring) should predict lightning timing better than ice signatures—particularly in warm clouds where the graupel mechanism cannot function. Pressure sensors cost less than ice-detection radar. Superior correlation would yield cheaper, faster lightning prediction for aviation safety, outdoor events, and power grid protection.

12.2 Static Electricity Control

If triboelectric charging is pressure-driven (rapid material separation → local pressure drop → voltage spike), then the rate of separation matters more than ambient humidity. Slow separation should dramatically reduce charge buildup regardless of humidity. Manufacturing environments (semiconductors, explosives, pharmaceuticals) could control static through mechanical process parameters—slower conveyor separation, controlled peel rates—rather than expensive humidity systems.

12.3 Wireless Power Transmission

Energy propagates as pressure waves in the vacuum; the Poynting vector ($E \times H$) determines energy flow direction. Wireless power transfer efficiency depends on field geometry, not conductor geometry. Redesigning wireless charging systems to optimise field coupling rather than attempting to ‘push’ energy through conductors—using energy flow analysis as developed by Schantz [10]—may lead to improved designs.

12.4 Antenna Efficiency

The reactive near-field represents energy oscillating before decoupling from the oscillon source—energy that has not yet become radiation. This is a physical process, not an unavoidable loss. Designing antennas that accelerate energy decoupling, reducing reactive storage and improving radiation efficiency, may allow the Chu limit to be approached through manipulation of decoupling dynamics rather than antenna size alone.

12.5 Earthquake Early Warning

If atmospheric electric field anomalies result from crustal density changes (as the field responds to mass redistribution at the speed of light, far faster than seismic P-waves), then field monitoring should detect precursors before mechanical rupture. Field mill networks along fault lines, correlated with seismic events, could potentially provide earlier warning than seismometer networks alone.

12.6 Pedagogical Clarity

Physics education research has documented persistent student misconceptions about electricity. These arise from conflating charge, current, energy, and field under a single word. The hydrodynamic framework provides unambiguous physical definitions:

Electric field (E): Pressure gradient in the vacuum. **Magnetic field (B):** Rotation (vorticity) of the vacuum medium. **Electric current (I):** Drift of oscillons through the medium. **Electrical energy:** Pressure waves propagating at c. **Voltage (V):** Pressure difference between two points. **Resistance (R):** Impedance to oscillon drift.

These definitions resolve the common paradoxes directly. The ‘consumption paradox’ (electricity flows in loops yet is consumed): charge (oscillons) flows in loops and is conserved; energy (pressure waves) flows one-way and is converted. The ‘velocity paradox’ (electrons drift slowly yet signals propagate at c): signal speed is the speed of sound in the vacuum; drift speed is how fast oscillons move through the medium. The ‘location paradox’ (energy in wires vs. in fields): energy travels as pressure waves in the vacuum surrounding conductors; wires are waveguides, not energy conduits.

13. Open Questions and Future Work

This framework does not claim completeness. Several areas require further theoretical development:

Strong Nuclear Force. While electromagnetism and gravity emerge naturally, the strong force remains to be incorporated. Volovik’s work suggests colour charge may relate to additional topological degrees of freedom of the ^{3}He-A order parameter.

Weak Force and Symmetry Breaking. The electroweak unification and Higgs mechanism require translation into superfluid language.

Precise α Derivation. Meucci’s wave closure calculation is promising but requires peer review and independent verification before it can be considered established.

Phase-Locking Mechanism. The universal temporal phase coherence required for gravity via the Bjerknes mechanism is physically motivated but not yet derived from first principles.

TZS Experimental Status. The null result for Transverse Zero Sound in normal liquid ^{3}He [7] means the identification of light with transverse acoustic modes must rely on the superfluid phases, where the order parameter provides richer internal structure. The precise relationship between TZS in the collisionless regime and the transverse modes observed in superfluid phases requires further theoretical clarification.

14. Conclusion

This paper has presented a comprehensive reformulation of classical electromagnetism within the non-viscous ether framework. The central identifications are:

Electric field: Pressure gradient in the vacuum. **Magnetic field:** Vorticity (rotation) of the vacuum medium. **Electric charge:** Topological defect (oscillon) with quantised winding number. **Speed of light:** Transverse acoustic velocity in the chiral superfluid vacuum. **Gauge invariance:** Phase symmetry of the condensate wavefunction.

The four critical objections to ether theories—transverse polarisation, fine structure constant, QED precision, and gauge invariance—all find resolution within the framework, though with appropriate caveats: the fine structure derivation awaits independent verification, and the experimental status of TZS requires careful distinction between normal and superfluid phases.

This reformulation does not overthrow Maxwell or QED. It provides what they lack: physical ontology. The equations remain; what changes is our understanding of what the equations describe. Fields are not abstract mathematical conveniences but dynamic properties of empty space—the non-viscous ether whose behaviour is governed by the mathematics of superfluid hydrodynamics.

Maxwell was right: there is a medium. Relativity was not wrong: the medium cannot be detected by motion through it, because observers are made of the medium's excitations. Both insights coexist in the non-viscous ether.

Electromagnetism is the acoustics and vorticity of empty space. Light is the transverse song of the vacuum. Charge is the resonant structure of stable waves. And the universe, far from being featureless, is rich with the dynamic properties from which everything arises.

Table: Complete Framework Synthesis

Standard Physics	**Hydrodynamic Electromagnetism**
Vacuum is empty geometry	Vacuum is non-viscous ether (^{3}He-A universality class)
Charge is intrinsic property	Charge is topological defect / winding number
Light is fundamental boson	Light is transverse acoustic mode of chiral superfluid
c is geometric constant	c is acoustic velocity
$\alpha \approx 1/137$ is empirical	α explored via vortex wave closure (awaiting verification)
Monopoles mysteriously absent	$\nabla\cdot(\nabla\times v) \equiv 0$ geometrically

Gauge symmetry is abstract	Gauge symmetry is phase coherence
QED is fundamental theory	QED is effective field theory of superfluid fluctuations
EM and gravity unrelated	Both are Bjerknes force (phase constraint differs)
Hierarchy problem unsolved	Ratio of oscillon to vacuum energy

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