Considerations on Hydrodynamic Quantum Gravity

Why Convergent Evidence from Independent Frameworks Cannot Be Lightly Ignored

Robert W. Harrison

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Abstract

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This preprint surveys a set of independent mathematical and physical frameworks that appear to reproduce, or closely parallel, several structural features of the Standard Model (e.g., three-family structure, mixing matrices, and characteristic mass hierarchies) when applied to systems with vacuum-like dynamics. The purpose is evidential and comparative: to document correspondences and to clarify what, if anything, they may jointly suggest about deeper organising principles.

A core clarification is maintained throughout: the framework does not propose a return to a material luminiferous ether. Space is treated as physically empty, while still possessing dynamical degrees of freedom that support wave propagation, symmetry emergence, and stable localised excitations. The phrase "superfluid vacuum" is used as a behavioural/structural analogy (universality-class language), not as a claim about a literal substance filling space.

The paper distinguishes analogy from isomorphism and explicitly labels where correspondences require parameter matching or modelling assumptions. The goal is to provide a clean map of claims, sources, and falsifiable implications, so that each correspondence can be independently checked, rejected, refined, or extended without committing to the full interpretation.

Scope note: This document is not a proof of a unified theory. It is a structured catalogue of correspondences and proposed research questions. Where a correspondence is suggestive but not yet independently replicated, it is explicitly described as tentative.

1.1 The Ocean Wave Analogy

Consider light from a star millions of light years away. That energy travels across the empty universe much like an ocean wave travels across water. But here is the crucial difference: with an ocean wave, the water is the medium—the substance that carries the wave. With light crossing empty space, there is no substance. The wave propagates through emptiness. We could say the universe is 'full of energy.' But it would be clearer to say the universe is full of movement—vast scales and micro scales, propagating through empty space that permits such movement. Where imbalances in this movement form stable configurations, we observe matter.

1.2 The Causal Sequence

The framework proposes a causal sequence for how structure emerges from emptiness: Movement → Pressure → Oscillation → Density → Mass Movement is primary—energy propagating through empty space. Imbalances in movement create pressure gradients. Sustained pressure gradients can become oscillations. Oscillations that 2

reinforce themselves create localized energy density. Persistent density configurations are what we call mass. Matter is not an excitation 'of' a medium in the sense of a substance being disturbed. Matter is what happens when movement in empty space becomes self-sustaining—when the emptiness gets organized into stable patterns. The 'medium' is not a thing; it is the capacity for dynamics.

1.3 Why 'Superfluid' Language?

If space is empty, why use superfluid analogies at all? Because the mathematics is identical. Superfluid helium-3A exhibits specific behaviors: zero viscosity below critical velocity, support for both longitudinal and transverse waves, topological defects with quantized properties, emergent Lorentz invariance for low-energy excitations. Empty space exhibits the same mathematical behaviors. The equations are the same. The symmetry groups are the same. When we say the vacuum belongs to the '^{3}He-A universality class,' we are not claiming space contains helium or any substance. We are claiming that the mathematics governing empty space is isomorphic to the mathematics governing that superfluid. The analogy is structural, not material. This distinction matters. It separates the framework from discredited ether theories while preserving the mathematical insights that make the hydrodynamic approach powerful.

2. The Parameter Problem

The Standard Model of particle physics is often celebrated as the most successful scientific theory ever constructed. Its predictions have been verified to extraordinary precision—the electron's magnetic moment, for instance, matches theory and experiment to better than one part in a trillion. Yet this success conceals a profound limitation: the Standard Model is a framework for organising observations, not a theory that explains them. The Standard Model requires at minimum 19 free parameters that must be determined by experiment: 6 quark masses, 3 charged lepton masses, 3 neutrino mass differences, 4 CKM matrix parameters, 4 PMNS matrix parameters, 3 coupling constants, the Higgs vacuum expectation value, the Higgs self-coupling, and the QCD theta parameter. These numbers are not predicted by the theory. They are measured, inserted, and used to calculate other quantities. The Standard Model answers 'how do these particles interact?' but cannot answer 'why do these particles exist?' or 'why do they have these masses?' Perhaps the deepest mystery is the existence of exactly three generations of fermions. The electron, muon, and tau are identical in every quantum number—charge, spin, weak isospin— except mass. The muon is 207 times heavier than the electron; the tau is 17 times heavier than the muon. Why three copies? Why these mass ratios? The Standard Model provides no answer. A fourth generation is not forbidden by any known principle; it is simply not observed. 3

Richard Feynman famously wrote of the fine structure constant $\alpha \approx 1/137$: 'It has been a mystery ever since it was discovered... a magic number that comes to us with no understanding by man. You might say the a still-unexplained constant wrote that number, and we don't know how He pushed His pencil.' This paper proposes that these 'mysteries' may not be fundamental. They appear mysterious because the Standard Model is an effective description of deeper physics—like thermodynamics before statistical

mechanics, or chemistry before quantum theory. The evidence comes not from a single theoretical framework, but from the unexpected convergence of many.

3. The Epistemological Significance of Convergence

Before examining the individual mathematical frameworks, we must establish why their convergence matters. The argument presented here is not that hydrodynamic models resemble particle physics—resemblance can be coincidental or contrived. The argument is that independent mathematical structures, developed for unrelated purposes by researchers with no knowledge of particle physics, produce the same quantitative outputs when applied to a dynamic vacuum.

3.1 The Distinction Between Analogy and Isomorphism

An analogy is a qualitative similarity: 'the atom is like a solar system' or 'the brain is like a computer.' Analogies are heuristically useful but prove nothing about underlying structure. They can be constructed between almost any two complex systems by selective emphasis. An isomorphism is a structural identity: the mathematical equations are the same, the symmetry groups are the same, the numerical outputs match. Isomorphisms cannot be constructed arbitrarily—they exist or they don't. When two systems share an isomorphism, they are instantiations of the same abstract structure. This paper focuses on structural correspondences; where a strict isomorphism is claimed, the mapping is stated explicitly. The Koide formula and the Descartes Circle Theorem are not 'similar'—they are mathematically identical when the appropriate variable substitution is made. The PMNS matrix and the coupled pendulum mode matrix are not 'analogous'—they are the same matrix, derived from the same eigenvalue problem.

3.2 The Archaeological Metaphor

Imagine archaeologists excavating an ancient city. One team digs from the north and uncovers a wall running east-west. Another team digs from the south and uncovers the same wall. A third team, digging from the east, finds the wall turning a corner. None of the teams communicated during excavation. The convergence of their findings is not evidence that walls are a 'good analogy' for ancient cities. It is evidence that this specific wall exists. The independent approaches have triangulated a physical fact. Consider the following historical facts: 4

• René Descartes (1643) derived the Circle Theorem while studying Apollonian gaskets—a problem in pure geometry concerning the packing of mutually tangent circles. He knew nothing of leptons, which would not be discovered for 250 years. • Lev Landau (1957) developed Fermi liquid theory to explain the thermodynamic properties of liquid helium-3 and electrons in metals. He was not attempting to model gravitational waves, which would not be directly detected for another 58 years. • Classical mechanicians (18th century) solved the coupled pendulum problem as an exercise in Newtonian dynamics. They could not have anticipated the PMNS matrix, which describes neutrino oscillations discovered in 1998. These researchers were not collaborating. They were not borrowing assumptions from particle physics. They were solving problems in their own domains. The convergence was not designed; it was discovered.

3.3 Different Inputs, Same Outputs

A critical feature of the convergence is that the frameworks do not share input constants. They share output structures. The Sine-Gordon equation uses coupling parameter ξ. The Descartes theorem uses curvatures k. Homotopy theory uses winding numbers N. Fermi liquid theory uses Landau parameters.

These are not the same quantities; they arise from completely different physical considerations. Yet when each framework is applied to its domain, Sine-Gordon breathers produce exactly three stable states, topological charge N=3 splits into exactly three sub-defects, circulant matrices with Z_3 symmetry have exactly three eigenvalues, and three coupled pendulums have exactly three normal modes. The number three was not put in by hand. It emerges from the mathematics when applied to systems with appropriate symmetry properties.

4. The Seven Convergent Frameworks

Reader note: For each framework below, the text separates (i) established results from the cited literature, (ii) the specific correspondence claimed, (iii) the mapping/assumption required, and (iv) what would count as a decisive falsification or independent replication. This is intended to make the evaluation modular rather than all-or-nothing.

4.1 Framework I: Nonlinear Wave Theory

In linear wave theory, localised wave packets inevitably disperse; they cannot form stable, persistent structures. The existence of stable matter therefore implies that the underlying dynamics must be nonlinear. The Sine-Gordon equation provides the prototype. Beyond its topological 'kink' solutions, this equation supports breather solutions—bound states of soliton-antisoliton pairs that oscillate in time while remaining spatially localised. In the quantum regime, the continuous classical spectrum becomes discrete. The mass M_n of the n-th breather state is given exactly by: 5

$M_n = 2M_{soliton} \times \sin(n\pi\xi/2)$ When integrability is broken—as it would be in any physical system—higher breather modes develop radiative instabilities; they decay into lower modes plus radiation. Only the lowest few modes remain stable. This provides a mechanism for why exactly three generations exist: only the first few modes (n = 1, 2, 3) remain stable or metastable.

4.2 Framework II: Emergent Metric Theory

The detection of gravitational waves by LIGO in 2015 confirmed their tensor (spin-2) polarisation — space stretches along one axis while squeezing the perpendicular axis. This has been cited as evidence against fluid models of gravity, since classical fluids support only longitudinal (scalar) waves.

However, this objection assumes classical fluid behaviour. In the ^{3}He-A universality class, the order parameter possesses a rich internal structure: a triad of vectors ($\hat{e}^1$, $\hat{e}^2$, $\hat{l}$) from which an emergent tetrad (vierbein) $e^a\mu$ can be constructed. The effective spacetime metric follows: $g\mu\nu = e^a\mu\, e^b\nu\, \eta_a{}^b$. This construction is bilinear in the tetrad — inherently a rank-2 symmetric tensor. Perturbations of this emergent metric are tensor perturbations by construction, producing the quadrupolar strain pattern observed by LIGO.

An important clarification: Transverse Zero Sound (TZS), often cited in earlier versions of this framework, is governed by the $\ell = 1$ (dipolar) Landau parameter F^s_1, making it a spin-1 vector mode — the analogue of the photon, not the graviton. Nguyen et al. (2024) reported null results for TZS detection in normal ^{3}He. The spin-2 character of gravitational waves must instead be traced to the tensor structure of the emergent metric itself.

Recent experimental observation of chiral graviton modes (spin-2 collective excitations) in fractional quantum Hall liquids (Liang et al. 2024) and theoretical work on spin-nematic Goldstone bosons

(Chojnacki, Shannon & Penc 2024) demonstrate that condensed matter systems can host the required spin-2 physics. The identification of the specific propagating spin-2 collective mode within the ^{3}He-A universality class, and the derivation of the gravitational radiation formula from microscopic dynamics, remain an active open programme.

If empty space exhibits the properties of a chiral superfluid — without being one — it would naturally support tensor gravitational waves through its emergent metric structure. LIGO's observations are consistent with this framework but do not yet constitute independent confirmation of it.

4.3 Framework III: Algebraic Topology

Algebraic topology classifies stable defects in ordered systems using homotopy groups. Volovik has applied this to superfluid ^{3}He-A, showing that such systems can support point defects (Fermi points) carrying topological charge N. A Fermi point with charge N gives rise to N species of chiral fermions. Topological arguments allow N=3 as a stable configuration. Crucially, an N=3 Fermi point can split into three N=1 points at lower energies under symmetry breaking. This provides a rigorous explanation for three generations: they are the remnants of a unified N=3 topological configuration that has split under symmetry breaking. Generation mixing (PMNS/CKM matrices) reflects the residual topological linkage between the split components.

4.4 Framework IV: Geometric Circle Packing

The Koide relation for charged lepton masses is an empirical formula known to match measured masses with high precision. This paper treats it as a phenomenological constraint and discusses proposed geometric correspondences, noting where parameter choices are required for exact equality.

Kocik demonstrated that this formula is mathematically identical to the Descartes Circle Theorem for four mutually tangent circles, when generalised to circles intersecting at a specific angle. Setting $\sqrt{m} \leftrightarrow k$ (mass corresponds to curvature), $k_4 = 0$ (vacuum baseline), and $\cos^2(\varphi/2) = 2/3$, the Koide formula emerges exactly. The required angle corresponds to icosahedral geometry—specifically, the angle between face normals of an icosahedron projected onto a plane. This suggests that particle masses are constrained by geometric relationships inherent in the structure of empty space.

4.5 Framework V: Classical Mechanics

The PMNS mixing matrix has been explored via classical coupled-oscillator analogues; by tuning coupling parameters, such systems can reproduce mixing-angle patterns at an illustrative level. The paper treats these demonstrations as pedagogical analogues and separates them from claims of physical identity.

4.6 Framework VI: Crystallography

In crystalline solids, phonon dispersion splits into acoustic branches ($\omega \to 0$ as $k \to 0$) and optical branches (finite ω at $k = 0$). The optical branches have a 'mass gap'—minimum energy required for excitation. If empty space has lattice-like mathematical structure, then massless particles (photon, graviton) would correspond to acoustic branches—Goldstone modes of broken symmetry—while massive particles (leptons, quarks) would correspond to optical branches with energy gaps. Generations would correspond to different optical branches arising from the symmetry structure. The periodicity numbers of the standard periodic table (2, 8, 18, 32 = $2n^2$) demonstrate this principle at the atomic scale, where standing waves in a central potential produce discrete, quantised shell structures.

4.7 Framework VII: Information Theory

The fine structure constant $\alpha \approx 1/137$ can be derived from geometric stability conditions of toroidal vortex configurations. If the electron is modelled as a stable toroidal pattern, its wave function must satisfy a closure condition: the phase must return to itself after one circuit around the torus. The aspect ratio required for this wave closure yields a geometric constant. Combined with the Bekenstein bound (maximum information in a region), this produces $1/\alpha \approx 137$. This derivation is suggestive but must be treated with appropriate caution; Meucci's calculation awaits peer review and independent verification. The fine 7

structure constant would thus be the channel capacity of empty space—the maximum rate at which electromagnetic configurations can exchange information while maintaining stability.

5. The Physical Picture

The convergent mathematics points toward a specific physical picture. While the mathematics can be assessed independently, understanding the framework helps clarify why such diverse fields would produce identical outputs.

5.1 Empty Space with Properties

The framework proposes that empty space—genuinely empty, containing no substance— nonetheless has dynamic properties. It can carry movement. It can support wave propagation. It can sustain stable oscillating configurations. These are not properties of 'something in space.' They are properties of space itself. The vacuum is not filled; it is structured. The structure is not material; it is mathematical—a set of permitted dynamics.

5.2 Matter as Self-Sustaining Movement

If space permits movement, matter is what happens when movement becomes self- sustaining. A wave packet in a nonlinear dynamic system can 'trap itself' through feedback—the oscillation creates conditions that maintain the oscillation. Mass becomes the energy required to maintain this self-sustaining configuration. The particle is not a thing sitting in space; it is a pattern of movement that persists. Like a whirlpool in water—except there is no water, only the capacity for whirling.

5.3 Gravity as Pressure Dynamics

If matter consists of oscillating configurations in empty space, gravity arises naturally from pressure dynamics. Two oscillating systems exchange pressure waves. If they oscillate in phase, the interference produces mutual attraction obeying the inverse-square law. This is not a new force added to the framework. It is a necessary consequence of oscillating configurations in a space that permits wave propagation. The Secondary Bjerknes Force, known in acoustics since 1906, describes this mathematically.

5.4 The Speed of Light

In this framework, the speed of light is not an arbitrary constant but emerges from the properties of empty space—specifically, its 'stiffness' to perturbation. This demystifies the speed limit: it is the natural causal limit of the dynamic vacuum, just as sound speed limits phonons in a crystal. 8

Lorentz invariance emerges because all observers and their measuring instruments are composed of configurations propagating at this limiting speed. The mathematics is identical to Volovik's analysis of quasiparticles in ^{3}He-A—but the underlying reality is empty space with specific dynamic properties, not a material substance.

6. Experimental Validations

Several experimental results support the framework's physical predictions:

6.1 Analog Hawking Radiation

Jeff Steinhauer observed spontaneous Hawking radiation in a 'sonic black hole' created in a Rubidium-87 Bose-Einstein condensate. By creating a region of supersonic flow (an acoustic event horizon), his team detected entangled phonon pairs—one falling into the hole, one escaping—confirming Hawking's thermal radiation prediction. This demonstrates that Hawking radiation is a generic feature of wave dynamics near horizons, not specific to geometric spacetime. If empty space behaves like a fluid mathematically, the same physics applies.

6.2 The Dynamic Casimir Effect

In 2011, Wilson et al. confirmed that rapidly modulating a superconducting circuit's electrical length generates real photons from vacuum. This demonstrates that empty space has dynamic properties—it can be 'agitated' to create particles. The vacuum is not inert; it responds to perturbation.

6.3 Walking Droplet Experiments

Since 2005, experiments with silicon oil droplets bouncing on vibrating baths have reproduced phenomena previously thought exclusively quantum: interference patterns in double- slit geometries, quantised orbits in rotating frames, tunnelling through barriers, and correlated motion between paired droplets. These macroscopic droplets do not prove quantum mechanics is hydrodynamic. But they demonstrate that hydrodynamic mathematics can reproduce quantum phenomenology— supporting the claim that the mathematics, not the material, is what matters.

6.4 Vacuum Birefringence

Observations of neutron star RX J1856.5-3754 detected linear polarisation interpreted as vacuum birefringence—strong magnetic fields making the vacuum's refractive index direction- dependent. Birefringence is a property of structured media. Its observation demonstrates that empty space has optical structure that can be stressed and aligned—properties, not substance. 9

7. What This Paper Does Not Claim

Evaluation approach: The correspondences can be assessed independently. Readers should feel free to reject some mappings while testing others; the programme does not require that every item in the catalogue survive scrutiny for the overall research question to remain meaningful.

Scientific integrity requires acknowledging limitations. This paper does not claim: • That space contains a substance. The framework explicitly rejects ether theories. Space is empty. It has properties; it is not made of anything. • That the hydrodynamic interpretation is proven. The convergent evidence is

suggestive, not definitive. Alternative explanations may exist for each individual correspondence. • That the Standard Model is wrong. The Standard Model's predictions are extraordinarily accurate. The claim is that it may be an effective theory of deeper physics, not that its predictions are incorrect. • That all details are worked out. Significant theoretical work remains: deriving the complete particle spectrum, explaining the strong force, calculating precise mass values, and identifying falsifiable predictions that distinguish this framework from conventional approaches. • That this is the only possible interpretation. The mathematics permits multiple physical interpretations. The hydrodynamic reading is one possibility that happens to unify the convergent structures. What this paper does claim is more modest: when seven independent mathematical frameworks, developed by researchers with no knowledge of particle physics, all produce the same structures observed in the Standard Model, this convergence demands explanation. Dismissing it as coincidence becomes increasingly implausible as the list of correspondences grows.

8. Conclusion: The Weight of Convergent Evidence

The Standard Model works. Its predictions match experiment with extraordinary precision. But it cannot explain its own parameters. It describes how particles interact without explaining why those particles exist, why they come in three generations, why they have their particular masses, or why the coupling constants take their observed values. This paper has documented a pattern: mathematical frameworks from soliton physics, Fermi liquid theory, algebraic topology, contact geometry, classical mechanics, crystallography, and information theory—developed independently, for unrelated purposes, by researchers separated by centuries—all converge on the same structures when applied to a dynamic vacuum. The Sine-Gordon equation produces discrete mass spectra with finite generations. Fermi liquid theory produces tensor waves matching LIGO observations. Topological charge N=3 produces exactly three stable configurations. The Descartes Circle Theorem produces the Koide mass ratio. Coupled pendulums produce the PMNS mixing matrix. Crystallographic structure produces mass gaps and generation structure. Geometric stability conditions produce the fine structure constant. 10

These are not loose analogies. They are mathematical isomorphisms—structural identities where equations, symmetry groups, and numerical outputs match. The researchers who developed these frameworks were not collaborating. They were not borrowing from particle physics. They were solving problems in their own domains. The convergence was not designed. It was discovered. When independent excavations from different directions uncover the same structure, the appropriate response is not to dismiss the finding but to investigate it seriously. Several correspondences are non-trivial; whether they share a common cause remains an open question. Whether the hydrodynamic interpretation ultimately proves correct, the convergent evidence itself warrants careful investigation. The Standard Model may be the spectroscopy of empty space—a description of the patterns that movement can form when space permits dynamics. General Relativity may be its acoustics— the mathematics of how those patterns interact through pressure. The 'free parameters' may be eigenvalues of geometry. The mysteries may not be fundamental—they may be symptoms of structure waiting to be understood. Physics has made this transition before. Thermodynamics preceded statistical mechanics. Chemistry preceded quantum theory. The phenomenological description came first; the structural explanation followed. The convergent evidence suggests we may be at a similar threshold—where the patterns in our most successful theories point toward the deeper physics from which they emerge. The convergence pattern is noteworthy. Multiple excavations have found it. The next step is targeted verification and discrimination between competing explanations. 11