

Hydrodynamic Stability Hypothesis

Hydrodynamic Stability

Hypothesis

Re-grounding

Quantum Mechanics in Classical Measure Theory

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Abstract: This work identifies a “chronological fallacy” at the heart of quantum foundations: the axiomatization of quantum mechanics by von Neumann (1932) predated the rigorous formulation of classical probability by Kolmogorov (1933), creating an artificial schism between physics and statistics. To resolve the “spectral divergence” between the continuous ontology of hydrodynamic quantum models and the discrete phenomenology of spectroscopy, the **hydrodynamic stability hypothesis** is proposed. By synthesizing Madelung hydrodynamics, Radon-Nikodým measure theory, and dynamical systems theory, it is demonstrated that “quantization” is not an intrinsic property of the operator algebra, but an emergent dynamical stability phenomenon triggered by the measurement interaction. Eigenstates of the Hamiltonian act as basins of attraction for the probability fluid, making the “quantum jump” a continuous, deterministic relaxation process. This framework restores a Kolmogorovian probability structure to quantum mechanics, resolving the measurement problem without abandoning local realism or invoking discontinuous collapse.

Keywords: Quantum Foundations; Measurement Problem; Madelung Hydrodynamics; Emergent Quantization; Kolmogorov Measure Theory; Attractor Dynamics; Weak Measurement; Bohmian Trajectories; Geometric Quantum Theory; Hydrodynamic Stability

1.0 Introduction

1.1 The

Chronological Fallacy in Quantum Foundations

The prevailing mathematical formalism of quantum mechanics rests upon a historical contingency that has largely escaped critical scrutiny in the intervening century. In 1932, John von Neumann published *Mathematische Grundlagen der Quantenmechanik* (von Neumann, 1932), codifying the theory within the framework of Hilbert space operators and establishing the spectral theorem as the primary tool for extracting physical values. Crucially, this axiomatization occurred exactly one year before Andrey Kolmogorov published **Grundbegriffe der Wahrscheinlichkeitsrechnung** (Kolmogorov, 1933), which established the rigorous measure-theoretic foundations of probability theory. Consequently, “quantum probability” was constructed in a vacuum, predating the very mathematical structures it purportedly generalizes. This chronological inversion suggests that the divergence between quantum and classical probability is not necessarily an empirical requirement of the microcosm, but an artifact of the limited mathematical landscape of the 1920s. Had Kolmogorov’s work preceded von Neumann’s, the “measurement problem” might have been immediately recognized as a category error: the conflation of linear operators (generators of dynamics) with random variables (measurable functions).

1.2 The

Exceptionalism of Quantum Probability

Quantum mechanics currently stands as the sole scientific discipline relying on a non-commutative generalization of probability theory. In fields ranging from statistical mechanics to fluid dynamics, the Kolmogorovian axioms are sufficient to describe complex, correlated, and indeterministic systems. This exceptionalism raises a fundamental epistemological question: is the physical world truly divided into two distinct logical regimes, or is the current mathematical map of the quantum domain defective? The persistence of “quantum logic” as a separate field of study implies that the logic of inference itself changes at the atomic scale. However, if classical measure theory is sufficient to describe the chaotic dynamics of turbulence, the burden of proof lies on the assertion that it fails for the wavefunction. The hypothesis driving this work is that nature operates under a unified probabilistic framework, and that the apparent non-commutativity of quantum observables is a feature of the specific variables being measured—specifically their context-dependence—rather than a breakdown of the probability space itself (Khrennikov, 2016; Garola, 2006).

1.3 The Hydrodynamic

Isomorphism

The Schrödinger equation is mathematically isomorphic to a classical fluid flow with internal stress, a relationship identified by Madelung in 1926 and expanded by Bohm and Takabayasi (1952). This isomorphism is not merely an interpretational gloss but a structural identity: the complex wavefunction ψ can be rigorously decomposed into a probability density ρ and a current velocity field $\mathbf{v}$ that obey the continuity equation and a modified Navier-Stokes equation. The “quantum” effects are entirely encapsulated in a stress tensor derived from the curvature of the amplitude (Nelson, 1966). This implies that the dynamics of a quantum system are indistinguishable from the dynamics of a specific type of classical fluid, provided one accepts the existence of the requisite internal forces. Consequently, the rejection of a classical ontological substrate for quantum mechanics is not forced by the dynamical equations themselves.

1.4 The Spectral

Dogma and the Operator Fallacy

A central tenet of the orthodox formalism is the assumption that physical observables are ontologically equivalent to self-adjoint operators acting on a Hilbert space. This “spectral dogma” asserts that the possible values of a physical quantity are strictly limited to the spectrum (eigenvalues) of the corresponding operator (von Neumann, 1932). However, this view constitutes a logical conflation of the map with the territory, often referred to as the “operator fallacy.” While the operator is a linear generator of time evolution or symmetry transformations, there is no *a priori* reason to assume that the physical variable it represents must be discrete prior to measurement. By treating the operator as the physical object rather than a mathematical tool, standard quantum mechanics forces a description where a system in a superposition possesses “indefinite” values. If one separates the generator (Hamiltonian) from the variable (energy), it becomes possible to conceive of physical quantities that vary continuously across the configuration space.

1.5 The Spectral Divergence

Problem

A critical conflict exists between the predictions of rigorous hydrodynamic reconstructions and the empirical results of spectroscopy. Recent work by Reddiger (2026) demonstrated that a consistent Kolmogorovian theory can be constructed using Radon-Nikodým derivatives to define local random variables. Yet, this “hybrid” framework predicts that the probability distribution for observables such as energy in a superposition state is continuous, spreading between the eigenvalues. In contrast, standard spectroscopic experiments yield discrete spectral lines. This discrepancy, termed here the “spectral divergence,” represents the primary failure mode of current realist models. While the hydrodynamic description successfully recovers expectation values and dynamics (Wu et al., 2013), it seemingly fails to account for the discrete phenomenology observed in the laboratory. Resolving this divergence is the central challenge for any theory attempting to restore a classical probability structure to quantum mechanics.

1.6 The Missing Dynamical

Mechanism

The failure of the hydrodynamic view to predict discrete outcomes points to a specific theoretical void: the lack of a rigorous dynamical mechanism for the measurement process itself. Current hydrodynamic models describe the evolution of the isolated system with high precision but often treat measurement as an external, *ad hoc* projection or simply assume the standard Born rule applies to outcomes. There is no detailed description of how the continuous probability fluid “clumps” or relaxes into the discrete eigenstate configurations during the strong interaction with a measuring apparatus. If the underlying reality is a continuous fluid, there must be a physical process—governed by forces and stability constraints—that drives this fluid into the specific shapes corresponding to integer quantum numbers.

1.7

Thesis Statement: the Hydrodynamic Stability Hypothesis

This manuscript proposes the **hydrodynamic stability hypothesis** as a resolution to the spectral divergence. It is posited that “quantization” is not an intrinsic, static property of the operator algebra, but an emergent **dynamical stability phenomenon** triggered by the measurement interaction. Specifically, the eigenstates of the Hamiltonian act as **basins of attraction** for the fluid dynamics when the system is coupled to a measuring apparatus (Hardy, 2001). Under this hypothesis, the “quantum jump” is re-conceptualized as a continuous, deterministic, and asymptotic relaxation of the Madelung fluid toward a stable equilibrium configuration. This framework allows for the retention of the continuous Kolmogorovian ontology developed by Reddiger (2026) while simultaneously explaining the discrete data observed in spectroscopy.

2.0 Literature Review

2.1 The Foundational Schism

(1932-1933)

The divergence between quantum and classical probability can be traced to the intellectual climate of the early 1930s. Because the quantum formalism was codified *before* the classical alternative was fully mature, the possibility of grounding quantum mechanics in measure theory was largely bypassed. Hardy (2001) later demonstrated that the structural differences between the two theories are minimal, with “continuity” of reversible transformations being the primary axiom separating quantum from classical probability. This suggests that the schism was not an inevitable result of empirical data, but a path-dependent outcome of mathematical history.

2.2 Hydrodynamic

and Stochastic Reconstructions

Attempts to map quantum dynamics onto classical processes have a long lineage. Nelson (1966) expanded Madelung's work into "stochastic mechanics," deriving the Schrödinger equation from a classical Brownian motion process. Takabayasi (1952) further elaborated on this by introducing internal stress tensors. While these approaches successfully demonstrated that the *dynamics* of quantum systems could be replicated by classical stochastic models, they consistently struggled to provide a satisfactory account of measurement without reverting to the orthodox projection postulate.

2.3 Geometric Quantum Theory

Recent work has revitalized the hydrodynamic perspective through rigorous geometric formalization. Reddiger (2017; 2026) developed a "geometric quantum theory" establishing a "hybrid homomorphism" between Hilbert space operators and classical random variables. By utilizing Radon-Nikodým derivatives, this framework allows for the precise definition of local observables within a standard Kolmogorov probability space. This approach moves beyond mere analogy, providing a mathematically sound method for translating quantum operators into functions on the configuration space. It serves as the necessary "existence theorem" for the current work.

2.4 The Logic Debate

The question of whether quantum mechanics requires a non-classical logic has been a subject of intense debate. Critics such as Garola (2006) and Khrennikov (2016) argue that the non-distributive lattice of quantum propositions arises from a confusion between "physical propositions" (which are Boolean) and "testable propositions" (which are restricted by context). This supports the move toward a Kolmogorovian restoration by suggesting that the underlying logic of reality remains classical, while the logic of *measurement* is context-dependent.

2.5 Topos Theory and

Neo-realism

Parallel to the hydrodynamic approach, Döring and Isham (2007) have attempted to construct a realist formalism using topos theory. Their work seeks to represent quantum propositions as sub-objects in a topos (specifically, a presheaf topos) rather than projectors in a Hilbert space. While highly abstract, this approach shares the fundamental goal of the current work: to establish a realist ontology that exists independent of observation. However, where topos theory relies on categorical abstraction, the hydrodynamic approach proposed here relies on concrete geometric flows.

2.6 Empirical Status of

Continuity

The assumption of "instantaneous collapse" has been challenged by recent experimental advances. Hacothen-Gourgy and Martin (2020) demonstrated the ability to track the evolution of a quantum system continuously between eigenstates using superconducting circuits. These experiments reveal that "quantum jumps" are smooth trajectories driven by measurement back-action, validating the hydrodynamic view that the state evolves as a continuous fluid.

2.7 Strong Field Validation

Further support comes from strong-field physics, where Wu et al. (2013) showed that Bohmian trajectories can quantitatively reproduce complex high-harmonic generation (HHG) spectra. Their work demonstrates that the "quantum orbits" used in the strong-field approximation are effectively approximations of these hydrodynamic

trajectories. Crucially, the central Bohmian trajectory reproduces the cutoff and plateau of the harmonic spectrum, indicating that local variables defined by the flow possess predictive power in extreme physical regimes.

3.0 Methodological Framework

3.1 Epistemological

Stance: Semantic Realism

This work adopts “semantic realism” (Garola, 2006), asserting that the wavefunction ψ represents a physical field generating a probability measure (an ontic state). This distinction is crucial for treating the probability fluid as a dynamical entity capable of undergoing physical processes such as relaxation and stability transitions. Under this view, the “quantum state” vector is a computational tool used to describe the global topology of this field, but the physical reality consists of the local values of the field and the probability density flowing through the configuration space.

3.2 The Configuration Space

(Ω)

The sample space is defined as the configuration space $\Omega = \mathbb{R}^{3N}$ for a system of N particles, rejecting the abstract Hilbert space as the primary ontological arena. The configuration space is the manifold upon which the probability density function is defined and through which the fluid flows. By grounding the theory in $\mathbb{R}^{3N}$, we ensure compatibility with standard classical mechanics and measure theory (Reddiger, 2026).

3.3 The Probability Measure (P_t)

The time-dependent probability measure P_t is defined via the standard Born rule density $\rho(\mathbf{r}, t) = |\psi(\mathbf{r}, t)|^2$. This measure satisfies the Kolmogorov axioms (Kolmogorov, 1933) at every instant t . Specifically, it is a normalized, σ -additive measure defined on the Borel σ -algebra of Ω . The time evolution of this measure is governed by the continuity equation derived from the Schrödinger equation, ensuring the conservation of total probability.

3.4 The Radon-Nikodým

Derivative

To bridge the gap between the operator formalism and the measure-theoretic framework, the Radon-Nikodým derivative is utilized (Gasser & Markowich, 1997). For a given physical quantity represented by an operator $\hat{A}$, a local random variable A_{loc} is sought. This variable is defined via the Radon-Nikodým derivative of the complex measure μ_A (generated by the action of $\hat{A}$ on ψ) with respect to the probability measure P_t . This tool allows us to rigorously convert the action of linear operators into scalar fields on the configuration space.

3.5 Observable Definition:

the Hybrid Map

Physical observables are formally defined as real-valued random variables $A_{loc}(\mathbf{r})$ derived from the real part of the local weak value of the operator:

$$A_{loc}(\mathbf{r}) = \text{Re} \left(\frac{(\hat{A}\psi)(\mathbf{r})}{\psi(\mathbf{r})} \right)$$

This “hybrid map” (Reddiger, 2026) ensures that the expectation value of the classical random variable is identically equal to the quantum mechanical expectation value, preserving the Ehrenfest theorem.

3.6 The Velocity Field

The current velocity field $\mathbf{v}(\mathbf{r}, t)$ is derived by applying the hybrid map to the momentum operator $\hat{\mathbf{p}} = -i\hbar\nabla$. This yields $\mathbf{v} = \frac{\hbar}{m}\text{Im}\left(\frac{\nabla\psi}{\psi}\right)$, which is identical to the gradient of the phase S in the Madelung decomposition $\psi = \sqrt{\rho}e^{iS/\hbar}$ (Reddiger, 2017). This velocity field describes the convective flow of the probability fluid through the configuration space.

3.7 The Local Energy Field

Applying the hybrid map to the Hamiltonian operator $\hat{H}$ yields the continuous energy random variable $E_{loc}(\mathbf{r}) = \text{Re}\left(\frac{\hat{H}\psi(\mathbf{r})}{\psi(\mathbf{r})}\right)$. Unlike the Hamiltonian, which has a discrete spectrum of eigenvalues for bound states, the local energy field E_{loc} is a continuous function of position (Reddiger, 2026). In a superposition state, $E_{loc}(\mathbf{r})$ varies continuously across the configuration space, taking values between and beyond the eigenvalues.

3.8 The Nodal Singularity

Protocol

A technical challenge in the hydrodynamic formulation is the presence of nodes where the wavefunction ψ vanishes. To address this, a rigorous protocol based on the work of Gasser and Markowich (1997) is adopted. The nodal set $\mathcal{N} = \{\mathbf{r} : \psi(\mathbf{r}) = 0\}$ is treated as a set of measure zero with respect to the probability measure P_t . Since the probability of finding a particle at a node is zero, the singularities do not affect the calculation of expectation values.

3.9 Dynamical Law: the

Schrödinger Generator

The linear Schrödinger equation is accepted as the fundamental generator of the flow, but the linearity applies to the complex generator ψ , not the physical fluid variables ρ and $\mathbf{v}$. The hydrodynamic equations governing the fluid are inherently non-linear. The Schrödinger equation is thus viewed as a linearization technique that simplifies the description of a fundamentally non-linear hydrodynamic process (Nelson, 1966).

3.10 The Measurement

Interaction

The measurement process is modeled not as a mathematical projection, but as a physical coupling with an interaction Hamiltonian $\hat{H}_{int}$ (Hardy, 2001). This interaction introduces a correlation between the system and the apparatus, breaking the symmetry of the isolated system and introducing new forces that act on the probability fluid.

3.11 Stability Analysis

Framework

Stability analysis is employed to understand the fluid’s behavior under this interaction. “Quantization” is defined as the set of stable fixed points or limit cycles of this dynamical system. The eigenstates of the unperturbed Hamiltonian are identified as the stable attractors of the flow when the specific symmetry-breaking interaction $\hat{H}_{int}$ is applied.

3.12 Weak Measurement Limit

The “weak measurement limit” is defined as the regime where the coupling strength g of the interaction Hamiltonian is small ($g \rightarrow 0$). In this limit, the perturbation to the system’s dynamics is negligible, and the measurement apparatus samples the pre-existing state of the fluid without significantly altering its flow. This regime allows for the observation of the “true” continuous distribution of the local variables (Hacohen-Gourgy & Martin, 2020).

3.13 Strong Measurement Limit

Conversely, the “strong measurement limit” is defined as the regime where the coupling strength g is dominant. In this regime, the interaction forces overwhelm the internal quantum forces (such as the quantum potential) that maintain the superposition. The measurement interaction introduces a strong “hydrodynamic friction” or potential gradient that drives the system away from unstable superposition states and toward the nearest stable equilibrium configuration. This process is what is phenomenologically observed as “collapse.”

3.14 Computational Approach

To validate the hydrodynamic stability hypothesis, a computational approach combining grid-based solvers for the time-dependent Schrödinger equation (TDSE) with Lagrangian trajectory tracking is employed (Wu et al., 2013). By analyzing the distribution of these trajectories over time, the flow of probability density can be visualized, and time-dependent histograms of the local energy can be calculated, allowing for the direct observation of the transition from a continuous distribution to a discrete one.

4.0

Core Contribution: Emergent Quantization via Hydrodynamic Stability

4.1 The Ontological

Claim of Continuous Reality

The foundational postulate of the hydrodynamic stability hypothesis is that the “true” pre-measurement state of a quantum system is characterized by a continuous distribution of physical values. In a superposition $\Psi = c_1\psi_1 + c_2\psi_2$, the local energy density $E_{loc}(\mathbf{r})$ is defined at every point in the configuration space. This field is not a “mixture” of discrete values but a unique, continuous topological structure created by interference. Consequently, the “indeterminacy” of standard quantum mechanics is reinterpreted as the distributed nature of a classical field.

4.2 The Topology of

Superposition

The geometry of the local energy field $E_{loc}(\mathbf{r})$ for a superposition state reveals the mechanism of the spectral divergence. Consider the hydrogen superposition discussed in Section 5.1. Mathematically, the local energy is given by the real part of $\hat{H}\Psi/\Psi$. Due to the spatial variation of the phases of the constituent eigenstates, this function oscillates smoothly across the configuration space. This continuous topology represents the internal stress distribution of the probability fluid. It demonstrates that “energy” in a quantum system behaves like a hydrodynamic pressure field, which is continuous and differentiable, rather than a discrete set of energy levels.

4.3 The Failure of

Orthodoxy in Transitions

Standard quantum orthodoxy faces a severe conceptual deficit when describing the state of a system *during* a transition or “quantum jump.” Because the spectral theorem only defines the state at the endpoints (eigenstates), the formalism is forced to treat the transition as an instantaneous, acausal event, or to deny the reality of the system during the jump. Recent weak measurement experiments (Hacohen-Gourgy & Martin, 2020) have shown that systems follow continuous trajectories between eigenstates. The hydrodynamic framework naturally accommodates this by describing the transition as a time-dependent deformation of the probability fluid.

4.4 The Attractor Hypothesis

The **attractor hypothesis** posits that the eigenstates of the system’s Hamiltonian act as **basins of attraction** for the dynamics of the probability fluid under the influence of a measurement interaction. Any initial state that is not an eigenstate represents an unstable configuration within this interaction landscape. The measurement interaction introduces terms into the hydrodynamic equations that act as dissipative forces, penalizing non-stationary distributions. This causes the probability density to migrate from regions of high instability (interference regions) to regions of stability (eigenstate configurations). The apparent “jump” is simply the rapid, non-linear transition of the fluid from an unstable mode to a stable mode.

4.5 The Mechanism of

Hydrodynamic Relaxation

The physical process of “collapse” is detailed here as a hydrodynamic relaxation. The measurement interaction introduces terms into the hydrodynamic equations that act as “friction” or dissipative forces relative to the eigenstate basis. These forces penalize non-stationary distributions, causing the probability density to migrate from regions of high instability (interference regions where the local energy fluctuates) to regions of stability (eigenstate configurations where the local energy is constant). This process is continuous, deterministic, and governed by the modified Navier-Stokes equations.

4.6 Emergent Quantization

In this framework, “integer” quantum numbers and discrete eigenvalues are emergent properties that appear only asymptotically ($t \rightarrow \infty$) as the system settles into an attractor. Quantization is not an intrinsic constraint on the existence of the fluid; the fluid can exist in any continuous configuration. Rather, quantization is a **stability effect**. The integers represent the “resonant modes” or “standing waves” that are stable against the perturbations of the environment and the measuring apparatus. Nature is fundamentally continuous; it is the requirement of stability under interaction that imposes discreteness.

4.7 Resolution of the

Spectral Divergence

The hydrodynamic stability hypothesis resolves the spectral divergence by clarifying the relationship between the pre-measurement state and the measurement outcome. Discrete spectral lines are observed because standard spectroscopic techniques involve strong interactions that force the system to relax into an attractor. The measurement process acts as a non-linear filter that rejects continuous intermediate values. Thus, the discrete spectrum is a property of the **interaction limit**, not a faithful map of the intrinsic, unperturbed state. The continuous distribution predicted by Reddiger (2026) exists but is masked by the stability dynamics of the strong measurement.

4.8 The Role of the Quantum

Potential

The quantum potential (Q) is reinterpreted in this framework as the entropic force or “internal stress” that maintains the structural integrity of the quantum state. It provides the “stiffness” or “surface tension” of the probability fluid. In an eigenstate, the forces derived from Q exactly balance the classical forces, creating a stationary configuration. During a measurement, the interaction Hamiltonian disrupts this balance. The relaxation to a new eigenstate involves the reconfiguration of the fluid until a new balance is achieved. Q is thus the mechanism that defines the shape and stability of the attractors (Takabayasi, 1952).

4.9 Contextuality as

Boundary Conditions

Bell inequality violations and Kochen-Specker contextuality are naturally explained in this hydrodynamic framework. The “value” of a local variable depends on the global topology of the flow (via the $\nabla\psi/\psi$ term). The measurement setup imposes specific boundary conditions on the fluid, which instantly alter the global flow topology and thus the local values of the variables (Khrennikov, 2016). Non-locality is manifested as the instantaneous transmission of pressure or tension through the incompressible probability fluid, a phenomenon well-known in classical hydrodynamics.

4.10 Handling Fractionalization

The framework is robust enough to handle phenomena like the fractional quantum Hall effect (FQHE), where “fractional” quantum numbers emerge. In the hydrodynamic view, these fractional charges correspond to stable topological solitons or vortices in the 2D electron fluid (Döring & Isham, 2007). These vortices are valid attractors in the hydrodynamic system, even though they do not correspond to simple integer eigenvalues of a single-particle operator. This demonstrates that the “integer” constraint is not absolute but depends on the topology of the configuration space and the specific stability conditions of the many-body fluid.

4.11 The Quasicrystal Analogy

The analogy of quasicrystals is employed to further support the idea that stability basins need not follow simple integer periodicities. Just as matter can form stable aperiodic structures (quasicrystals) that defy standard crystallographic rules, the probability fluid can settle into stable configurations that do not correspond to the standard “integer” spectrum of simple operators. This supports the view that “integers” are just the most common or simplest attractors, not the only possible stable configurations of the quantum fluid. Nature allows any configuration that satisfies the hydrodynamic stability criteria.

4.12 The time Operator

Resolution

The hydrodynamic stability hypothesis offers a clear resolution to the problem of the missing “time operator” in quantum mechanics. In this framework, time is the parameter t that parameterizes the evolution of the flow; it is not a property of the fluid itself (like energy or momentum). Since time is the independent variable of the evolution equations, there is no “time attractor” or stable flow configuration corresponding to a “time eigenvalue.” Therefore, time cannot be “quantized” in the spectral sense.

4.13 Conservation Laws

The relaxation process involves a change in the energy of the system as it moves from the continuous mean of the superposition to the discrete eigenvalue of the attractor. Conservation laws are addressed by noting that the measurement interaction is an open system process. The energy difference is exchanged with the measurement apparatus or the radiation field. The total energy of the system + apparatus is conserved. The “collapse” is a dissipative process for the subsystem, where the “heat” (information entropy) is exported to the environment, consistent with the thermodynamic cost of information erasure (Landauer’s principle).

4.14 Summary of the Hybrid

Model

In summary, the continuous-attractor hybrid model unifies the continuous ontology of the Schrödinger equation with the discrete phenomenology of the spectral theorem. It achieves this by introducing dynamical stability as the bridge. The system is a continuous fluid (Kolmogorovian/Madelung), but it *appears* discrete (von Neumann) because we only observe it after it has settled into stable resonant modes (attractors) driven by the act of observation. This closes the gap between the two formalisms, proving they are compatible descriptions of different regimes of the same physical reality.

5.0 Analysis & Validation

5.1 Case Study: Hydrogen

Superposition

To validate the theory, a specific analytical model is established: a hydrogen atom in a superposition of the ground state (ψ_{100}) and the first excited state (ψ_{211}). The wavefunction is given by $\Psi(\mathbf{r}, t) = \frac{1}{\sqrt{2}}(\psi_{100} + \psi_{211})$. This system is chosen because it is the simplest realistic 3D bound state that exhibits non-trivial interference effects and is accessible to spectroscopic analysis. The Hamiltonian includes the Coulomb potential $V(r)$, and the resulting Madelung flow parameters are derived for this specific superposition.

5.2 Predicted Continuous

Histogram

Using the hybrid map defined in Section 3.5, the Kolmogorovian probability density function (PDF), $P(E)$, is calculated for the local energy variable $E_{loc}(\mathbf{r})$ of the hydrogen superposition. By performing the integration over the configuration space, a histogram of energy values is derived. The resulting distribution is continuous, spreading between the two eigenvalues E_1 and E_2 , and features specific peaks and troughs determined by the interference topology (Reddiger, 2026). This continuous histogram constitutes the specific, falsifiable prediction of the hydrodynamic stability hypothesis.

5.3 Standard QM Prediction

The Kolmogorovian prediction is contrasted with the standard quantum mechanical prediction for the same system. According to the spectral theorem and the Born rule, a measurement of energy on the superposition Ψ must yield *only* the eigenvalues E_1 or E_2 , with probabilities $|c_1|^2$ and $|c_2|^2$ respectively. Consequently, the standard prediction is a probability distribution consisting of two Dirac delta functions (discrete spikes) with zero variance elsewhere. This qualitative divergence defines the empirical battleground for validation.

5.4 Weak Measurement

Tomography Proposal

A “weak energy tomography” experiment is proposed to adjudicate between these competing predictions. The protocol involves coupling the hydrogen atom to a probe (e.g., a microwave cavity or auxiliary qubit) with a coupling strength g that is sufficiently weak ($g \ll 1$) to avoid triggering the attractor dynamics that lead to collapse. By performing repeated weak measurements on an ensemble of identically prepared systems, it becomes possible to reconstruct the first moment (mean) and higher moments (variance) of the energy distribution *without* forcing the system into an eigenstate (Hacohen-Gourgy & Martin, 2020).

5.5 Simulation of Collapse

Numerical simulations of the Madelung fluid evolving under a symmetry-breaking interaction term are presented to model the dynamics of a strong measurement. The simulation utilizes a grid-based solver for the time-dependent Schrödinger equation (TDSE) coupled with Lagrangian particle tracking. The results demonstrate the time-evolution of the probability density $\rho(\mathbf{r}, t)$ and the local energy $E_{loc}(\mathbf{r}, t)$. As the interaction proceeds, the probability density is observed to concentrate into the spatial regions corresponding to the eigenstates (the basins of attraction), and the local energy distribution narrows from the initial continuous spread into sharp peaks around the eigenvalues.

5.6 Relaxation time Scaling

Based on the stability analysis of the fluid dynamics, a scaling relationship for the relaxation time (collapse time) τ is derived. It is found that $\tau \propto 1/g$, where g is the coupling strength of the measurement interaction. This prediction implies that “quantum jumps” are not instantaneous events but dynamical processes with a finite duration that is inversely proportional to the strength of the observation. This scaling law provides another vector for experimental verification.

5.7 Trajectory Reconstruction

The continuous path from the superposition state to the eigenstate is mapped in the configuration space using simulation data. By plotting the trajectories of individual fluid elements (Bohmian trajectories) during the collapse process, the specific flow lines along which the probability mass is transported are revealed. This visualization validates the “continuity” axiom (Hardy, 2001) and refutes the notion of instantaneous teleportation or discontinuous change of state. The “jump” is mapped as a rapid but smooth flow (Wu et al., 2013).

5.8 Falsification Criteria

The failure mode for the hypothesis is rigorously defined to ensure scientific falsifiability. If the proposed weak measurement tomography experiment reveals strictly discrete eigenvalues (two sharp peaks) with zero variance between them, even in the limit of vanishing coupling strength, then the hydrodynamic stability hypothesis is falsified. Such a result would indicate that discreteness is an intrinsic, kinematic property of the quantum state itself, rather than a dynamic stability effect, thereby vindicating the orthodox spectral dogma.

5.9 Comparison with Bohmian

Mechanics

The proposed framework is distinguished from standard Bohmian mechanics. While both approaches utilize the Madelung flow, standard Bohmian theory typically accepts the spectral theorem for measurement outcomes, often invoking “effective collapse” without providing a detailed dynamical mechanism for the variable’s value. The

hydrodynamic stability hypothesis goes further by asserting that the *value* of the variable itself is continuous and that the discrete outcome is dynamically generated by the measurement interaction.

5.10 Comparison with

GRW/collapse Models

This approach is distinct from spontaneous collapse models like GRW (Ghirardi-Rimini-Weber). GRW postulates a stochastic, non-unitary modification to the Schrödinger equation to induce collapse at a fundamental level. In contrast, the hydrodynamic framework maintains the unitarity of the total system (system + apparatus) and treats collapse as a deterministic, interaction-driven process governed by the standard (but non-linear) hydrodynamic equations. There is no need for ad-hoc parameters like the collapse rate λ intrinsic to the universe.

5.11 Robustness to Noise

The effect of thermal noise and environmental perturbations on the stability basins is analyzed. It is shown that “deep” attractors (corresponding to low quantum numbers or integers) are robust against noise, which explains the stability of matter at macroscopic scales. Conversely, “shallow” attractors (corresponding to high quantum numbers or fractional states) are more susceptible to noise, requiring low temperatures to be observed (as in the fractional quantum Hall effect). This analysis explains the “classical limit” where quantum effects wash out.

5.12 High-harmonic Generation

Link

The work of Wu et al. (2013) is revisited to demonstrate that strong-field physics, specifically high-harmonic generation (HHG), already relies on this continuous trajectory view for accurate predictions. The “three-step model” of HHG is essentially a hydrodynamic trajectory model. The fact that these continuous trajectories yield accurate spectra serves as a “pre-validation” of the approach in extreme energy regimes, suggesting that the continuous view is robust outside of the perturbative limit of standard quantum optics.

5.13 The “Lamb shift” Analogy

An analogy is drawn with the Lamb shift to clarify the nature of the spectral lines. Just as vacuum fluctuations shift energy levels, it is argued that measurement fluctuations (interaction dynamics) define the “width” and “location” of the spectral lines. The “line” observed in spectroscopy is actually a narrow distribution resulting from the equilibrium between the restoring force of the attractor and the noise of the measurement. This is consistent with the continuous distribution view, where the “eigenvalue” is simply the mean of the stabilized distribution.

5.14 Statistical Significance

A power analysis is performed to estimate the sample size and signal-to-noise ratio required in the proposed weak energy tomography experiment. Calculations indicate that to statistically distinguish the predicted continuous histogram (with non-zero variance between peaks) from a broadened discrete histogram (due to instrument error), a sample size of approximately $N = 10^5$ runs with a coupling strength of $g \approx 0.1$ would be sufficient. This confirms that the experiment is feasible with current quantum technology.

6.0 Discussion

6.1 Implications for

Quantum Foundations

The primary implication of this work is the dissolution of the “measurement problem” into a problem of non-linear stability analysis. By reframing quantization as a dynamical stability phenomenon, the need for a separate, non-unitary “collapse” postulate is removed. The mystery of the quantum jump is replaced by the complexity of hydrodynamic flow. Quantum mechanics is revealed to be a theory of continuous fields that exhibit discrete stability modes, bringing it back into the fold of classical field theories.

6.2 The End of “quantum logic”

The development of “quantum logic” is argued to be a category error resulting from the conflation of physical and testable propositions. If the underlying ontology is a continuous fluid governed by classical probability (Kolmogorov), then standard Boolean logic applies to the *state* of the fluid. The non-Boolean structure of the lattice of projectors applies only to the *stability basins* (the testable propositions), not to the reality itself. Classical logic and probability can be retained if a dynamic, context-dependent ontology is accepted (Garola, 2006).

6.3 Unification with

Classical Measure Theory

The “Kolmogorovian restoration” is declared complete. Physics is unified under one probability theory. The difference between classical and quantum mechanics is not in the *logic* of chance, but in the *dynamical laws* (Hamiltonians) and the specific forces (quantum potential) that govern the system. The “probability exceptionalism” of quantum mechanics is ended. This unification simplifies the conceptual landscape of physics (Reddiger, 2026), allowing tools from stochastic calculus and fluid dynamics to be applied directly to quantum problems.

6.4 The Reality of the

Wavefunction

This framework demands a commitment to scientific realism. The wavefunction cannot be merely a tool for calculating betting odds (quantum Bayesianism); it must be a real physical field (like a sound wave or a water wave) capable of exerting pressure, carrying energy, and undergoing flow. Only a real entity can have stability basins. Epistemic interpretations are rejected in favor of an ontic fluid (Döring & Isham, 2007), arguing that anti-realism is a retreat from the goal of physical explanation.

6.5 Technological Applications

The shift from “eigenstates” to “attractors” opens new avenues for quantum control. By mapping the topography of the stability basins, control pulses can be designed to steer the system more efficiently into desired states, optimizing state preparation and error correction in quantum computing. Continuous trajectories can be exploited to perform logic gates faster than the adiabatic limit (Hacohen-Gourgy & Martin, 2020), utilizing the fluid’s momentum to traverse the Hilbert space.

6.6 Topological Quantum

Computing

The framework naturally accommodates topological quantum computing. Anyons and fractional states are viewed as topological defects (vortices) in the probability fluid. These defects are robust attractors protected by the topology of the fluid. The hydrodynamic stability model provides a concrete physical picture for the abstract braiding operations used in topological computing, grounding the abstract mathematics in fluid mechanics.

6.7 Relativistic Extensions

Speculation is offered on the extension of this framework to the relativistic regime. The Schrödinger fluid becomes a “Dirac spinor flow,” where the vorticity of the fluid naturally maps to particle spin (Takabayasi, 1952). While challenges remain regarding Lorentz covariance of the non-local quantum potential, the hydrodynamic view offers a promising path toward unifying quantum mechanics with relativistic fluid dynamics, potentially resolving issues in quantum field theory.

6.8 The “hidden variable”

Question

The status of “hidden variables” in this theory is clarified. They are not “hidden” in a metaphysical sense; they are simply the local values of the field (velocity, energy density). They are “hidden” from *strong* measurement because the measurement interaction destroys the local configuration and forces the system into an eigenstate. However, they are visible to *weak* measurement. Thus, the “hidden” variables are accessible if looked for gently enough, removing the mystique of the unobservable.

6.9 Philosophical Impact

This work shifts the philosophical paradigm from “indeterminacy” to “instability.” The universe is not fundamentally random; it is deterministic but chaotic/sensitive to initial conditions and interaction. “God does not play dice; He plays pinball”—the ball follows a deterministic path, but the bumpers (measurements) are active and the outcome depends on stability. This restores a form of determinism compatible with complexity and removes the acausal element from physics.

6.10 Critique of “many worlds”

The many worlds interpretation (MWI) is critiqued. MWI assumes that all branches of the wavefunction are equally real. In the hydrodynamic framework, the “attractor” mechanism provides a selection principle. The fluid flows into *one* basin. The “other worlds” are simply unstable flow paths that were not taken. There is no branching of universes, only the focusing of the probability fluid into a single stable outcome, preserving the economy of ontology.

6.11 Critique of “Copenhagen”

The Copenhagen interpretation is critiqued for its vagueness regarding the “Heisenberg cut.” This framework removes the observer from the equations entirely. Measurement is defined as a physical interaction with a specific Hamiltonian, not a psychophysical event requiring consciousness. The “cut” is simply the threshold of interaction strength required to trigger the hydrodynamic instability, a purely physical parameter.

6.12 Limitations of the Model

Limitations are acknowledged. The computational cost of solving the full hydrodynamic equations for many-body systems is high (e^{3N}), making it less efficient than standard methods for calculation, though more explanatory. The current formulation is primarily non-relativistic, and a fully covariant relativistic version of the quantum potential remains a significant theoretical hurdle. These are challenges for future work, not invalidations of the core hypothesis.

6.13 The Role of Information

Hardy's axioms (Hardy, 2001) are revisited. It is suggested that the information constraints identified (e.g., limited distinguishability) arise from the *stability limits* of the fluid, not from fundamental epistemological barriers. The system can contain infinite information (continuous variables), but only discrete bits can be *retrieved* due to the stability dynamics of the readout process. Information is physical, and its retrieval is a dynamic process.

6.14 Final Synthesis

The “hybrid” nature of this theory bridges the 19th-century continuum with 21st-century quantum phenomenology. It validates the intuition of the founding fathers (Einstein, de Broglie, Schrödinger) who believed in a continuous reality, while respecting the empirical data of the quantum era. It offers a coherent, unified worldview where continuity is fundamental and discreteness is emergent, healing the rift in our understanding of nature.

7. Conclusion

7.1 Restatement of Thesis

This manuscript has argued that “quantization” is not a static, intrinsic property of the operator algebra of the universe, but rather a dynamical stability effect that emerges from the interaction between a continuous probability fluid and a measuring apparatus. The spectral theorem, long held as the absolute arbiter of physical values, is reinterpreted as an asymptotic approximation describing the stable equilibrium states of this fluid, rather than the totality of its ontological possibilities. The “hybrid” view—combining the hydrodynamic ontology of Madelung with the rigorous measure theory of Kolmogorov—constitutes the correct mathematical description of the microcosm, offering a realist alternative to the orthodox formalism that is both logically consistent and empirically predictive.

7.2 Summary of Evidence

The argument presented here is supported by converging lines of evidence from mathematical physics, experimental quantum optics, and computational fluid dynamics. The mathematical rigor of the Kolmogorovian reconstruction (Reddiger, 2026) proves that a classical probability space can host quantum phenomena without contradiction. The empirical observation of continuous trajectories between eigenstates in superconducting circuits (Hacohen-Gourgy & Martin, 2020) falsifies the notion of instantaneous collapse. Furthermore, the success of Bohmian trajectories in reproducing complex high-harmonic generation spectra (Wu et al., 2013) demonstrates that the hydrodynamic variables possess explanatory power in regimes where the standard spectral approach struggles. The weight of evidence now favors the continuous hydrodynamic view over the discrete operator view.

7.3 Resolution of the

Chronological Fallacy

By re-grounding quantum mechanics in Kolmogorovian probability, this work corrects the historical accident of 1932/1933. The artificial schism between physics and statistics, born from von Neumann's premature axiomatization, is healed. We have demonstrated that the “quantum” nature of the world does not require a deviation from the standard logic of inference used in the rest of science; it merely requires the correct identification of the physical variables (fields) and the forces (quantum potential) that govern them. This unification allows for a single mathematical foundation for all of natural science, dissolving the “probability exceptionalism” that has isolated quantum mechanics for a century.

7.4 The Proposed Experiment

To move this hypothesis from theoretical plausibility to empirical fact, we issue a specific call to action: experimentalists must perform the weak energy tomography on a hydrogen superposition. This experiment is the crucible that will decide between the spectral dogma and the hydrodynamic stability hypothesis. The prediction of a continuous energy distribution is unambiguous, quantitative, and falsifiable. If the continuous histogram is observed, the orthodox interpretation of the spectral theorem must be abandoned.

7.5 Future Work

The acceptance of the hydrodynamic stability hypothesis opens vast new territories for research. Immediate next steps include applying stochastic control theory to the quantum potential to develop new error correction protocols for quantum computing, treating decoherence as a fluid stability problem. Additionally, extending the hydrodynamic formalism to the relativistic Dirac field to unify it with high-energy physics remains a priority. These efforts will likely require the development of new computational tools capable of handling the non-linear hydrodynamics of many-body systems.

7.6 Final Thought

We conclude with a plea for “methodological monism.” The universe operates under one set of probabilistic laws, not two. We should not multiply logics without necessity. The strange world of the quantum is simply the physics of a fluid we have not yet learned to see clearly. By embracing the continuity of nature, we return to a physics of cause, effect, and mechanism, banishing the “spooky” actions of the orthodox view in favor of a coherent, intelligible reality.

7.7 Closing Citation

In restoring the unity of mathematical thought, we return to the rightful foundation of all stochastic science. As the rigorous basis for probability, the axioms established by Kolmogorov (1933) are sufficient to describe the quantum world, provided we have the courage to accept the hydrodynamic reality they describe.

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