

Quantization as Hydrodynamic Relaxation: Eigenstates as Attractor Basins in a Dissipative Madelung Fluid

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Abstract

We develop a research program in which quantum jumps are reinterpreted as continuous, deterministic relaxation events in the Madelung hydrodynamic picture of quantum mechanics, where the wavefunction $\psi = \sqrt{\rho} e^{iS/\hbar}$ becomes a compressible fluid with density ρ and velocity $\mathbf{v} = \nabla S/m$. Adding a minimal linear drag term to the momentum equation leaves the continuity equation untouched, so stationary eigenstate densities remain exact fixed points of the flow; we show by explicit linearization that perturbations about the harmonic-oscillator ground state decay at rate $\gamma/2$ for every wavenumber, with an overdamped crossover at $\gamma = \hbar k^2/m$, and by a Lyapunov-energy argument that the damped flow is contractive. We compute closed-form level-to-level relaxation times $t_{n \rightarrow n-1} = \ln[(n + \frac{1}{2})/(n - \frac{1}{2})]/(2\gamma)$, giving $t_{1 \rightarrow 0} = 0.549306/\gamma$, a per-period phase-space contraction factor 0.881895 at $\gamma/\omega = 0.01$, and a diffusive-versus-relaxative timescale hierarchy $t_D \approx 2.2 \times 10^{-13} \text{ s} \ll \tau_E = 1.0 \times 10^{-9} \text{ s}$ for stated parameters. Born-rule statistics are carried as an explicitly labeled assumption, not derived. We connect the program to rigorous relaxation limits in quantum hydrodynamics, hydrodynamic attractors in kinetic theory, and measured qubit relaxation, and we specify a falsification protocol. No simulation results are reported; all numerical claims are analytic derivations or labeled projections.

1. Introduction

The standard interpretation of quantum mechanics treats measurement as a discontinuous, fundamentally stochastic event: the "collapse" of the wavefunction onto an eigenstate. This discontinuity sits awkwardly beside the continuous, deterministic unitary evolution governing everything else. The program developed here takes a different route, beginning from the Madelung formulation, in which the Schrödinger wavefunction is rewritten as the density and velocity field of a compressible, irrotational fluid. We add a minimal dissipative term to the quantum Hamilton–Jacobi equation and investigate:

Central hypothesis (H). With a suitable dissipative term, the Madelung flow is contractive, and each Hamiltonian eigenstate is a basin of attraction of this flow. A "quantum jump" is then not a fundamental discontinuity but a continuous, deterministic relaxation event: the fluid flowing into the nearest eigenstate basin. Quantization — the discreteness of outcomes — is a property of the attractor landscape stabilized by measurement-like perturbations, not an intrinsic primitive of nature.

If H is correct, it re-grounds quantum statistics in classical measure theory: probability enters as ordinary measure over initial conditions in phase space, in the spirit of Kolmogorov, rather than as an irreducible postulate. Wavefunction collapse dissolves into relaxation with a computable timescale.

We are explicit about what this paper does and does not establish. It establishes the relaxation dynamics and fixed-point structure analytically. It does **not** derive the Born rule: the claim that relaxation endpoints are sampled with Born-rule weights over initial conditions is carried as a labeled assumption (Assumption B) throughout, and its failure is one of the primary falsifiers of the program. It also does **not** report numerical simulations; the double-slit and Stern–Gerlach protocols are specified, not executed. (An earlier draft of this work sketched preliminary double-slit convergence results; because those results could not be documented to the standard of the present analysis, they are withdrawn and listed as future work.)

The paper proceeds in three pillars: derivation of the dissipative Madelung equations and closed-form relaxation laws (Sections 3–4); stability analysis of eigenstate fixed points (Section 4); and a falsification protocol (Sections 3.3 and 6).

2. Background and Related Work

We review the supplied bibliography in its fixed order. Three entries ([9], [10], [11]) are QNFO corpus items whose supplied summaries contain no substantive text; we say so explicitly and use them only as pointers.

[1] Affine quantization. This work contrasts canonical quantization, built on the commutator $[Q, P] = i\hbar 1$, with affine quantization, built on $[Q, D] = i\hbar Q$ where $D \equiv (PQ + QP)/2$, and notes that canonical operators must fit $-\infty < P, Q < \infty$ while affine quantization accommodates half-line domains for Q , such as $0 < Q < \infty$, with the proposal extended even to quantum gravity. This is directly relevant: the Madelung density ρ is non-negative by construction, so the configuration variable of a hydrodynamic re-foundation naturally lives on a domain where affine-type quantization is the appropriate algebraic starting point.

[2] Tianyan quantum cloud platform. This entry describes a cloud-accessible superconducting quantum prototype, Tianyan-287, with 105 qubits and operational fidelities of 99.90% (single-qubit gates), 99.56% (two-qubit gates), and 98.7% (readout). We cite it as the experimental infrastructure context in which any alternative account of measurement must ultimately be tested; the entry supplies no further theoretical detail, and we draw no dynamical claims from it beyond these hardware facts.

[3] Time-relaxation limit for quantum hydrodynamics. This is the closest rigorous anchor for our program. The paper analyzes weak solutions of the quantum hydrodynamics (QHD) system with a collisional term on the one-dimensional torus and rigorously proves a time-relaxation limit toward the quantum drift-diffusion (QDD) equation, with global-in-time finite-energy weak solutions obtained by energy methods (the summary truncates at this point). It establishes, in a well-posed PDE setting, that adding collisional/dissipative structure to a quantum hydrodynamic system produces a well-defined relaxation limit rather than pathologies — precisely the mathematical behavior H requires, albeit targeting the QDD equation rather than eigenstate attractors.

[4] Hydrodynamic attractors for Gubser flow. This work solves the Boltzmann equation in the relaxation-time approximation using a hierarchy of angular moments of the distribution function, for an azimuthally symmetric, radially expanding, boost-invariant conformal system undergoing Gubser flow, comparing truncated moment solutions to the exact solution. Its conceptual export is the attractor picture: far-from-equilibrium dynamics rapidly loses memory of initial microdetails and converges onto a universal hydrodynamic trajectory. H transplants this attractor paradigm from relativistic kinetic theory to the Madelung fluid, with eigenstates replacing hydrodynamic constitutive relations as the attractors.

[5] Eigenvalues and eigenstates of the quantum Rabi model. This paper addresses the analytical solution of the quantum Rabi model, motivated by its widespread use in quantum optics, quantum computing, cavity QED, and nanoelectromechanical systems, and by the need to describe a two-level system coupled to an oscillator when the rotating-wave approximation fails. The Rabi model is a natural first testbed beyond the harmonic oscillator for our program: a discrete two-level structure whose eigenstate basins a hydrodynamic-relaxation account must reproduce. The supplied summary describes motivation and context rather than solution techniques, and we rely on it only for that context.

[6] Quantum simulation of nuclear dynamics in first quantization. This entry notes that real-time nuclear dynamics underpins predictions of cross sections relevant to terrestrial experiments and astrophysics, and that first-principles classical simulation is hindered by exponential resource cost, motivating scalable quantum simulation. Its relevance is as a stress-test domain: real-time scattering and transition events are exactly what a relaxation picture must re-describe as continuous flow between basins. The summary supplies no methodological detail beyond this motivation.

[7] Relaxation of excited qubit states in silicon quantum dots. This work treats relaxation of low-lying excited orbital, valley, and spin qubit states in ideal single-electron silicon quantum dots for quantum computing, reporting that relaxation times depend sensitively on dot size and external magnetic field, and that orbital relaxation times are generally short (the summary truncates there). This is the experimental face of relaxation in real quantum systems: excited states genuinely decay with parameter-dependent timescales. Our program makes a strong structural claim — that this decay is the same continuous relaxation mechanism that constitutes measurement — and must therefore confront the measured parameter dependence in devices of this type.

[8] Hydrodynamic attractor in periodically driven ultracold quantum gases. This paper states that hydrodynamic attractors are a universal phenomenon of strongly interacting systems describing hydrodynamic-like evolution far from local equilibrium, that rapid hydrodynamization of the Quark-Gluon Plasma underlies the success of hydrodynamic models of high-energy nuclear collisions, and that hydrodynamic attractors had so far been explored only in systems undergoing monotone

evolution (the summary truncates; the title indicates periodic driving). This is the most direct precedent for H's central move: attractor behavior in a quantum fluid under external driving, supporting the plausibility that time-dependent measurement-like perturbations can generate stable attractor basins in a Madelung fluid.

[9]–[11] QNFO corpus items. The supplied entries for [9] ("Hydrodynamic Stability Hypothesis"), [10] ("A Pre-Registered Falsification of Deterministic Measurement-Triggered Relaxation"), and [11] ("Hydrodynamic-Topological Continuum") contain no summary text. Their titles indicate an existing research thread on hydrodynamic stability, pre-registered falsification of deterministic relaxation, and hydrodynamic-topological continuum structure; no substantive claim about their content can be made from the supplied material.

In sum, the literature provides (i) rigorous precedent for dissipative relaxation limits in quantum hydrodynamics [3], (ii) an established attractor paradigm in classical and quantum hydrodynamics [4, 8], (iii) an algebraic framework suited to non-negative density domains [1], and (iv) experimental and application contexts in which relaxation and discrete outcomes coexist [2, 5, 6, 7]. What is missing — and what this paper supplies in preliminary form — is the specific identification of Hamiltonian eigenstates as attractor basins of a damped Madelung flow.

3. Methods

3.1 The Madelung formulation

Write the wavefunction in polar form $\psi(\mathbf{x}, t) = \sqrt{\rho(\mathbf{x}, t)} e^{iS(\mathbf{x}, t)/\hbar}$, with $\rho \geq 0$ the position density and S the phase action. Substituting into the Schrödinger equation $i\hbar \partial_t \psi = \hat{H} \psi$ with $\hat{H} = -\frac{\hbar^2}{2m} \nabla^2 + V$ and separating real and imaginary parts yields the Madelung system:

$$\partial_t \rho + \nabla \cdot (\rho \mathbf{v}) = 0, \quad (\text{M1})$$

$$\partial_t S + \frac{m}{2} |\mathbf{v}|^2 + V + Q = 0, \quad (\text{M2})$$

where $\mathbf{v} = \nabla S/m$ and

$$Q(\mathbf{x}, t) \equiv -\frac{\hbar^2}{2m} \frac{\nabla^2 \sqrt{\rho}}{\sqrt{\rho}}$$

is the quantum potential — the only place $\hbar$ enters the fluid equations beyond the definition of $\mathbf{v}$. Equation (M1) is an ordinary continuity equation; (M2) is a quantum Hamilton–Jacobi equation. Taking ∇ of (M2) gives the Newton-like form $m(\partial_t + \mathbf{v} \cdot \nabla) \mathbf{v} = -\nabla(V + Q)$.

3.2 The dissipative extension

We add the minimal linear dissipative term in the Newtonian form (the convention adopted here; see Appendix A):

$$m(\partial_t + \mathbf{v} \cdot \nabla) \mathbf{v} = -\nabla(V + Q) - m\gamma \mathbf{v}, \quad \gamma > 0. \quad (\text{M2-d})$$

Equivalently, one may write the damping as a phase relaxation $-\hbar\gamma \Phi[S]$ in (M2) with $\Phi[S] = (S - S_{ss})/\hbar$, where S_{ss} is the phase of the nearest stationary configuration; the two conventions differ in bookkeeping, not in the friction force $-m\gamma \mathbf{v}$ acting along the flow. The continuity equation (M1) is untouched: the fluid is damped, not leaked, so positivity of ρ and probability conservation are preserved. Crucially, since $\mathbf{v} = 0$ at every stationary eigenstate, the drag term vanishes there: eigenstates remain exact fixed points, and the question is their stability. All analysis is performed in dimensionless units $\hbar = m = \omega = 1$ unless stated otherwise; where SI values are used, the electron mass $m_e = 9.109 \times 10^{-31}$ kg and $T = 300$ K are stated model parameters, not measurements.

3.3 Numerical protocol (specified, not executed)

No simulation results are reported in this paper. The protocol to be executed and pre-registered is:

- **Double-slit test:** propagate the damped Madelung fluid through a double-slit potential in two dimensions; verify that individual trajectories remain continuous and deterministic for all t , and that the endpoint distribution over detectors converges to the interference pattern.
- **Stern–Gerlach test:** propagate a spin-fluid analogue through a field gradient; verify convergence to two spatially separated attractor basins.
- **Falsifier:** if trajectories exhibit any discontinuity, any step-size sensitivity in the endpoint distribution beyond numerical tolerance, or endpoint statistics stable across initial-condition ensembles but inconsistent with Born weights, hypothesis H fails in its current form.

4. Analysis

All inputs are either structural equations from Section 3 or explicitly stated assumptions. Every number is computed here, step by step.

4.1 Exact quantum potential of the oscillator ground state

Input 1: $V(x) = \frac{1}{2}m\omega^2 x^2$ and ground-state density $\rho_0(x) = \frac{1}{\sqrt{\pi}\sigma} e^{-x^2/\sigma^2}$ with $\sigma^2 = \hbar/(m\omega)$. Then $\sqrt{\rho_0} \propto e^{-x^2/(2\sigma^2)}$ and

$$\frac{d^2}{dx^2} \sqrt{\rho_0} = \left(\frac{x^2}{\sigma^4} - \frac{1}{\sigma^2} \right) \sqrt{\rho_0},$$

so

$$Q_q = -\frac{\hbar^2}{2m} \left(\frac{x^2}{\sigma^4} - \frac{1}{\sigma^2} \right) = \frac{\hbar^2}{2m\sigma^2} - \frac{\hbar^2 x^2}{2m\sigma^4}.$$

Substituting $\sigma^2 = \hbar/(m\omega)$: $\frac{\hbar^2}{2m\sigma^2} = \frac{\hbar^2 m\omega}{2m\hbar} = \frac{\hbar\omega}{2}$ and $\frac{\hbar^2}{2m\sigma^4} = \frac{\hbar^2 m^2 \omega^2}{2m\hbar} = \frac{m\omega^2}{2}$. Hence

$$Q_q(x) = \frac{\hbar\omega}{2} - \frac{m\omega^2 x^2}{2}.$$

Stationarity check: with $S_0 = \text{const}$, the Hamilton–Jacobi equation requires $V + Q_q = E_0$; indeed $V + Q_q = \frac{m\omega^2 x^2}{2} + \frac{\hbar\omega}{2} - \frac{m\omega^2 x^2}{2} = \frac{\hbar\omega}{2} = E_0$. The ground state is an exact fixed point of the Madelung flow, with or without drag.

4.2 Linearized attractor dynamics

Input 2: linearization about $(\rho_0, \mathbf{u}_0 = 0)$ with $\eta = \delta\rho/\rho_0$; to first order $\delta Q_q = -\frac{\hbar^2}{4m} \nabla^2 \eta$ (the factor $1/4$ arises because $\sqrt{\rho}$ is the differentiated field). For a plane wave $\eta \propto e^{i(kx - \Omega t)}$, $\delta Q_q = \frac{\hbar^2 k^2}{4m} \eta$. The linearized equations are $\partial_t \delta\rho + \rho_0 \partial_x \delta u_x = 0$ and $m \partial_t \delta u_x = -\partial_x \delta Q_q - m\gamma \delta u_x$. From continuity, $-i\Omega \eta + ik \delta u_x = 0$, so $\delta u_x = \Omega \eta / k$. Substituting:

$$\begin{aligned} -i m \Omega \frac{\Omega \eta}{k} &= -i k \frac{\hbar^2 k^2}{4m} \eta - m\gamma \frac{\Omega \eta}{k}, \\ \implies \Omega^2 + i\gamma \Omega - \frac{\hbar^2 k^4}{4m^2} &= 0, \\ \implies \Omega &= -\frac{i\gamma}{2} \pm \sqrt{\frac{\hbar^2 k^4}{4m^2} - \frac{\gamma^2}{4}}. \end{aligned}$$

Result: every mode decays as $e^{-\gamma t/2}$; the oscillation frequency $\omega_k = \sqrt{\hbar^2 k^4/(4m^2) - \gamma^2/4}$ is real (underdamped) when $\gamma < \hbar k^2/m$ and imaginary (overdamped) otherwise. Since $\text{Im } \Omega = -\gamma/2 < 0$ for all k whenever $\gamma > 0$, the ground-state density is a linearly stable attractor for every wavenumber.

Numerical instance (stated parameters $\gamma = 10^9 \text{ s}^{-1}$, $k = 10^7 \text{ m}^{-1}$, $m = m_e$): amplitude decay time $\tau_{\text{lin}} = 2/\gamma = 2.0 \times 10^{-9} \text{ s}$. Crossover: $\hbar k^2/m = (1.055 \times 10^{-34}) \times 10^{14}/(9.109 \times 10^{-31}) = 1.055 \times 10^{-20}/9.109 \times 10^{-31} = 1.16 \times 10^{10} \text{ s}^{-1}$. Since $10^9 < 1.16 \times 10^{10}$, this mode is underdamped: it rings at $\omega_k \approx \hbar k^2/(2m) = 5.8 \times 10^9 \text{ rad s}^{-1}$ while decaying at $\gamma/2$.

4.3 Energy decay and level-to-level relaxation

Input 3: under linear friction, the mechanical energy $E = \frac{1}{2}m\dot{x}^2 + \frac{1}{2}m\omega^2 x^2$ obeys $dE/dt = m\dot{x}\ddot{x} + m\omega^2 x\dot{x} = \dot{x}(-m\gamma\dot{x}) = -m\gamma\dot{x}^2$. Averaging over an orbit for weak damping ($\gamma \ll \omega$), $\langle \dot{x}^2 \rangle = E/m$, hence

$$\frac{dE}{dt} = -2\gamma E \implies E(t) = E_0 e^{-2\gamma t}. \quad (\text{D1})$$

E is the Lyapunov function of the theory: strictly decreasing except at fixed points, so the flow is contractive.

Input 4: oscillator eigenenergies $E_n = \hbar\omega(n + \frac{1}{2})$. The time to relax from level n to $n - 1$ follows from (D1):

$$t_{n \rightarrow n-1} = \frac{1}{2\gamma} \ln \frac{E_n}{E_{n-1}} = \frac{1}{2\gamma} \ln \frac{n + \frac{1}{2}}{n - \frac{1}{2}}.$$

For $n = 1$: $t_{1 \rightarrow 0} = \frac{1}{2\gamma} \ln \frac{3/2}{1/2} = \frac{\ln 3}{2\gamma} = \frac{1.098612}{2\gamma} = \frac{0.549306}{\gamma}$. For $n = 2$: $\ln(5/3) = \ln 5 - \ln 3 = 1.609438 - 1.098612 = 0.510826$, so $t_{2 \rightarrow 1} = \frac{0.510826}{2\gamma} = \frac{0.255413}{\gamma}$. Structural prediction: relaxation accelerates with excitation ($t_{2 \rightarrow 1} < t_{1 \rightarrow 0}$), since the fractional gap $\ln(E_n/E_{n-1})$ shrinks with n — a sharp, falsifiable signature of the linear-damping model, testable against the parameter-dependent relaxation times of silicon quantum dots [7].

Two-mode instance (stated parameters $\omega = 10^{12} \text{ rad s}^{-1}$, $\gamma = 10^9 \text{ s}^{-1}$): the excited-state population, proportional to excess energy in the two-mode sector, obeys $p_1(t) = p_1(0) e^{-\gamma t}$ with $\tau_E = 1/\gamma = 1.0 \times 10^{-9} \text{ s} = 1.0 \text{ ns}$. The gap is $\Delta E = \hbar\omega = 1.055 \times 10^{-34} \times 10^{12} = 1.055 \times 10^{-22} \text{ J}$; using $1 \text{ meV} = 1.602 \times 10^{-22} \text{ J}$, $\Delta E = 1.055/1.602 = 0.658 \text{ meV}$. This nanosecond-scale deterministic "jump time" is of the same order category as the parameter-dependent excited-state relaxation measured in silicon quantum dots [7]; we do not claim quantitative agreement with any specific measured value, since that entry's summary supplies no numbers.

4.4 Per-period phase-space contraction

Input 5: weak damping $\gamma/\omega = 0.01$; over one period $T = 2\pi/\omega$, the phase-space area element contracts by $e^{-2\gamma T}$. Then $\gamma T = 2\pi \times 0.01 = 0.062832$ and

$$e^{-2\gamma T} = e^{-0.125663} = 0.881895.$$

The radial contraction per period is $e^{-\gamma T} = e^{-0.062832} = 0.939115$. After $k = 10$ periods:

$$e^{-2\pi \cdot 10 \cdot 0.01} = e^{-0.628319} = 0.533488.$$

Ten periods shrink an initial ensemble to about 53.3% of its phase-space area — the quantitative content of the claim that measurement-like perturbations induce stability by contraction.

4.5 Timescale hierarchy: relaxation versus diffusion

Input 6: the overdamped (drift-diffusion) limit has diffusivity $D = k_B T/(m\gamma)$ (Einstein relation for drag coefficient $m\gamma$). At $T = 300 \text{ K}$: $k_B T = 1.381 \times 10^{-23} \times 300 = 4.143 \times 10^{-21} \text{ J}$; $m\gamma = 9.109 \times 10^{-31} \times 10^9 = 9.109 \times 10^{-22} \text{ kg s}^{-1}$; hence

$$D = \frac{4.143 \times 10^{-21}}{9.109 \times 10^{-22}} = 4.55 \text{ m}^2 \text{ s}^{-1}.$$

Diffusion time over $L = 1 \mu\text{m} = 10^{-6} \text{ m}$: $t_D = L^2/D = 10^{-12}/4.55 = 2.2 \times 10^{-13} \text{ s}$. Hierarchy: $t_D = 2.2 \times 10^{-13} \text{ s} \ll \tau_E = 1.0 \times 10^{-9} \text{ s}$, with ratio $\tau_E/t_D = 10^{-9}/2.2 \times 10^{-13} = 4.5 \times 10^3$. The flow first spreads density diffusively across the accessible region, then relaxes it onto the attractor — the opposite ordering from an instantaneous "jump," and a distinguishing signature of the hypothesis.

4.6 Hardware fidelity statistics (from [2])

Input 7 (from [2]): $F_1 = 99.90\%$, $F_2 = 99.56\%$, $F_r = 98.7\%$. In decimal form $f_1 = 0.9990$, $f_2 = 0.9956$, $f_r = 0.9870$. Arithmetic mean: $S = f_1 + f_2 + f_r = 0.9990 + 0.9956 + 0.9870 = 2.9816$; $\bar{f} = S/3 = 2.9816/3 = 0.993866 \dots$, i.e. $\bar{F} = 99.3866\% \approx 99.39\%$.

Qubit-weighted composite (weights 1, 2, 105): $C_1 = 0.9990$, $C_2 = 2 \times 0.9956 = 1.9912$, $C_r = 105 \times 0.9870 = 103.635$; $C_{\text{tot}} = 0.9990 + 1.9912 + 103.635 = 106.6252$; $N_{\text{ops}} = 1 + 2 + 105 = 108$; $F_{\text{eff}} = 106.6252/108 = 0.98727 \dots$, i.e. 98.73% . These are descriptive statistics of the reported hardware figures, used only to gauge the precision context of any future test, not as evidence for H.

4.7 What is not derived

The Born rule is not derived here. Under H, the endpoint distribution is a measure over initial conditions in the basin; the claim that this measure equals $|\langle \psi_{\text{in}} | \phi_n \rangle|^2$ is **Assumption B**, carried openly. Its status and falsification role are discussed in Section 6.

5. Results

We report only quantities computed in Section 4, plus clearly labeled projections.

Result 1 (fixed points and stability). Eigenstate densities are exact fixed points of the damped flow (Section 4.1); linearized perturbations decay at rate $\gamma/2$ for all k , with overdamped crossover at $\gamma = \hbar k^2/m$ (Section 4.2). For the stated instance $\gamma = 10^9 \text{ s}^{-1}$, $k = 10^7 \text{ m}^{-1}$: $\tau_{\text{lin}} = 2.0 \times 10^{-9} \text{ s}$, crossover rate $1.16 \times 10^{10} \text{ s}^{-1}$ (underdamped), $\omega_k \approx 5.8 \times 10^9 \text{ rad s}^{-1}$.

Result 2 (energy decay). $E(t) = E_0 e^{-2\gamma t}$ (Eq. D1), valid for $\gamma \ll \omega$ under orbit averaging.

Result 3 (relaxation times). $t_{1 \rightarrow 0} = 0.549306/\gamma$; $t_{2 \rightarrow 1} = 0.255413/\gamma$; general law $t_{n \rightarrow n-1} = \ln[(n + \frac{1}{2})/(n - \frac{1}{2})]/(2\gamma)$, decreasing in n . For the stated parameters $\omega = 10^{12} \text{ rad s}^{-1}$, $\gamma = 10^9 \text{ s}^{-1}$: $\tau_E = 1.0 \text{ ns}$, $\Delta E = 0.658 \text{ meV}$.

Result 4 (contraction). At $\gamma/\omega = 0.01$: per-period phase-space contraction factor 0.881895; after 10 periods, 0.533488.

Result 5 (timescale hierarchy). For the stated parameters: $D = 4.55 \text{ m}^2 \text{ s}^{-1}$, $t_D = 2.2 \times 10^{-13} \text{ s}$, $\tau_E/t_D = 4.5 \times 10^3$.

Result 6 (hardware statistics, from [2]). Average of the three reported fidelities: 99.39%; qubit-weighted composite: 98.73%.

Result 7 (labeled projection). Under the stated assumption that a measurement-like apparatus implements effective damping $\gamma = 10^6 \text{ s}^{-1}$ (an assumption about the apparatus, not a measurement), full first-level relaxation occurs within $t_{1 \rightarrow 0} = 0.549306 \times 10^{-6} \text{ s} = 5.49306 \times 10^{-7} \text{ s} \approx 0.55 \mu\text{s}$; the uncertainty is entirely the uncertainty in the assumed γ , the coefficient 0.549306 being exact to the digits shown ($\ln 3/2$). Requirement for discrete outcomes: $\gamma \tau_m \gg 0.549306$ for perturbation duration τ_m .

Result 8 (protocol status). The double-slit and Stern–Gerlach tests of Section 3.3 are specified but not executed; no simulation outcomes are reported.

6. Discussion

Limitations. The energy-decay derivation (D1) uses orbit averaging, valid only for $\gamma \ll \omega$; the strong-damping regime requires the full linearized analysis of Section 4.2, which is itself local in ρ_0 and assumes locally flat V . The Lyapunov argument establishes attractivity of the fixed-point set, not global convergence to a *unique* eigenstate: degenerate spectra, limit cycles, or chaotic attractors could prevent convergence to a single outcome. The identification of excited-state population with excess energy (Section 4.3) is a projection approximation, not a derivation from the field equations. The damping term is phenomenological; its microscopic origin, system-size dependence, and relation to environmental decoherence are open. Grid discretization in any future simulation could create spurious attractors; convergence tests in grid resolution are mandatory.

Failure modes. (i) Measurement perturbations that inject energy faster than dissipation removes it, producing persistent oscillations rather than relaxation. (ii) Endpoint statistics stable across initial-condition ensembles but inconsistent with Born weights — this falsifies Assumption B while leaving H's dynamics intact. (iii) Observed discontinuities or step-size sensitivity in trajectories — this falsifies H directly.

What would falsify the claims. The n -dependence of $t_{n \rightarrow n-1}$ (accelerating relaxation at higher excitation) is a sharp structural prediction; measured relaxation times in silicon-dot-like systems [7] that instead lengthen with excitation, or are independent of excitation, would falsify the linear-damping model in its current form. A pre-registered test in the spirit suggested by the corpus item [10] — whose supplied entry contains no summary text, so no specific content is attributed to it — should target exactly this: prepare a superposition, apply a controlled measurement-like kick, and check whether post-kick trajectories settle deterministically into single eigenstates with Born-rule frequencies.

Arguing against ourselves. The strongest objection is that linear drag on a Madelung fluid is ad hoc: nothing in the Schrödinger equation selects γ , and any value can be fitted post hoc. A second objection is that the attractor picture explains stability but not *selection*: without a derived measure-preservation condition (Assumption B), the framework predicts relaxation to *some* eigenstate but not with the right frequencies. A third is that the relaxation-limit result of [3] targets a drift-diffusion equation, not eigenstate attractors, so the rigorous anchor is analogical, not deductive. Progress requires either deriving γ and the basin measure from an underlying dynamics, or accepting them as phenomenological parameters to be fixed by the falsification protocol of Section 3.3. We regard the second route as the honest near-term position: the model makes structural predictions (the n -dependence of $t_{n \rightarrow n-1}$, the timescale ordering $t_D \ll \tau_E$, the contraction factor per period) that are independent of the fitted value of γ , and these are what a decisive test should target.

7. Conclusion

We have developed a hydrodynamic-relaxation research program in which quantum jumps are reinterpreted as continuous, deterministic relaxation events in a damped Madelung fluid. The established results are: (i) adding linear drag $-m\gamma\mathbf{v}$ to the Madelung momentum equation leaves the continuity equation untouched, so eigenstate densities remain exact fixed points (Section 4.1); (ii) linearization about the harmonic-oscillator ground state shows every perturbation mode decaying at rate $\gamma/2$, with an overdamped crossover at $\gamma = \hbar k^2/m$ (Section 4.2); (iii) the damped flow is contractive, with closed-form level-to-level relaxation times $t_{n \rightarrow n-1} = \ln[(n + \frac{1}{2})/(n - \frac{1}{2})]/(2\gamma)$, giving $t_{1 \rightarrow 0} = 0.549306/\gamma$ and $t_{2 \rightarrow 1} = 0.255413/\gamma$ (Sections 4.3–4.4); and (iv) a diffusive-versus-relaxative timescale hierarchy $t_D = 2.2 \times 10^{-13} \text{ s} \ll \tau_E = 1.0 \times 10^{-9} \text{ s}$ for the stated parameters (Section 4.5).

What is not established is equally explicit. The Born rule is not derived: the identification of the basin measure over initial conditions with $|\langle \psi_{\text{in}} | \phi_n \rangle|^2$ is carried as the openly labeled Assumption B, and its failure is a primary falsifier. No simulations were executed; the double-slit and Stern–Gerlach protocols are specified for pre-registered future execution (Section 3.3). The damping coefficient γ is phenomenological. The program stands or falls on whether the structural predictions — accelerating relaxation with excitation, deterministic continuous trajectories, and basin statistics matching Born weights — survive the falsification protocol; if they do, quantization ceases to be a primitive postulate and becomes a property of an attractor landscape.

References

- [1] A Simple Factor in Canonical Quantization yields Affine Quantization Even for Quantum Gravity. arXiv:2108.04083v1. <https://arxiv.org/abs/2108.04083v1> [2] Tianyan: Cloud services with quantum advantage. arXiv:2512.10504v2. <https://arxiv.org/abs/2512.10504v2> [3] The time-relaxation limit for weak solutions to the quantum hydrodynamics system. arXiv:2412.16800v2. <https://arxiv.org/abs/2412.16800v2> [4] Hydrodynamic attractors for Gubser flow. arXiv:2001.10756v2. <https://arxiv.org/abs/2001.10756v2> [5] Eigenvalues and Eigenstates of Quantum Rabi Model. arXiv:2104.12771v2. <https://arxiv.org/abs/2104.12771v2> [6] Quantum Simulation of Nuclear Dynamics in First Quantization. arXiv:2507.22814v3. <https://arxiv.org/abs/2507.22814v3> [7] Relaxation of excited spin, orbital, and valley qubit states in single electron silicon quantum dots. arXiv:1301.0260v2. <https://arxiv.org/abs/1301.0260v2> [8] Hydrodynamic attractor in periodically driven ultracold quantum gases. arXiv:2501.19240v2. <https://arxiv.org/abs/2501.19240v2> [9] QNFO: Hydrodynamic Stability Hypothesis [10] QNFO: A Pre-Registered Falsification of Deterministic Measurement-Triggered Relaxation [11] QNFO: Hydrodynamic-Topological Continuum

Appendix A. Divergence report

One substantive divergence arose between independent drafts of this manuscript, concerning the placement of the dissipative term. One draft wrote the damping as a phase relaxation $-\hbar\gamma\Phi[S]$ in the quantum Hamilton–Jacobi equation (M2), with $\Phi[S] = (S - S_{\text{ss}})/\hbar$ referenced to the nearest stationary configuration; the other wrote it as a friction force $-m\gamma\mathbf{v}$ in the Newtonian momentum equation (M2-d). The two conventions differ only in bookkeeping — taking ∇ of the phase relaxation reproduces the same friction force along the flow — and the main text adopts the Newtonian convention (M2-d) for concreteness, noting the equivalence in Section 3.2. A second, minor divergence concerned whether preliminary double-slit simulation results should be reported; the convention adopted here is to withdraw any undocumented results and list the double-slit test as specified-but-not-executed future work, since no results could be documented to the standard of the present analysis.

Appendix B. Claim attribution

Claim	Substance	Source drafts	Status
C1	Damped Madelung flow leaves eigenstate densities as exact fixed points	A, B, C	CONVERGENT
C2	Linearized perturbations decay at rate $\gamma/2$ for all k ; crossover at $\gamma = \hbar k^2/m$	A, B, C	CONVERGENT
C3	Level-to-level relaxation law $t_{n \rightarrow n-1} = \ln[(n + \frac{1}{2})/(n - \frac{1}{2})]/(2\gamma)$, decreasing in n	A, B	CONVERGENT
C4	Per-period phase-space contraction factor 0.881895 at $\gamma/\omega = 0.01$	A, B	CONVERGENT
C5	Timescale hierarchy $t_D \ll \tau_E$ for stated parameters	A, B, C	CONVERGENT
C6	Born rule carried as labeled Assumption B, not derived	A, B, C	CONVERGENT
C7	Damping written as phase relaxation $-\hbar\gamma\Phi[S]$ in (M2)	A	SINGLE (reconciled with C8 as equivalent bookkeeping; see Appendix A)
C8	Damping written as friction force $-m\gamma\mathbf{v}$ in (M2-d)	B, C	CONVERGENT (adopted)
C9	Report preliminary double-slit simulation results	A	SINGLE (withdrawn; see Appendix A)
C10	Hardware fidelity statistics computed from [2]	B, C	CONVERGENT
C11	Falsification protocol targeting the n -dependence of relaxation times	A, B, C	CONVERGENT