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A New Realism and Ontology for Quantum Foundations with an Initial Formalization Attempt:

A Conceptual Research Program Beyond Wave-Particle Duality

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Abstract

Quantum mechanics is empirically unmatched, yet its ontology remains unsettled. This paper advances a realist research program that treats wave–particle duality as a deep source of several tensions in quantum foundations, including measurement, localization, and wave–function collapse. It further argues that these issues are often intensified by hypostatization: the elevation of abstract elements of the formalism, especially the wave function, to the status of concrete physical entities without clear criteria for physical reality. To address this, the paper develops physical realism, a realist framework that regulates ontological commitment by explicit anti–hypostatization criteria. On that basis, it proposes an energistic ontology for quantum foundations at the quantum level. This gives rise to the hypothesis of a Universal Energy Field (UEF) and energy wave–forms as alternatives to the dualistic wave-particle framework. Although its main emphasis is on ontology, the paper introduces also an initial formal description of energistic dynamics in Appendix A. Its role is primarily to show that the paper's main conceptual claims can be mathematically tractable, with the UEF and energy wave–forms being expressed through primitive postulates, an initial regime–dependent dynamics, and a stationary condensation equation.

Keywords: quantum foundations; wave–particle duality; physical realism; energistic ontology; pre–spatiotemporal dynamics.

1. Introduction

Quantum mechanics provides remarkably accurate predictions, yet the nature of its underlying reality remains a topic of debate [3] [10] [21]. Various interpretations often utilize the same operational formalism but differ in their claims about mind–independent reality. This persistent plurality of interpretations is commonly described as underdetermination, where multiple, metaphysically incompatible explanations seem to align with the same experimental results [6].

This paper advocates for a realist perspective while questioning two prevalent trends in current foundational discussions. First, it views duality as a fundamental source of several core challenges: if quantum objects are compelled to switch between incompatible classical categories, one must clarify how wave–like behavior leads to single localized events without relying on *ad hoc* additions. Second, the paper contends that many realist approaches to these challenges tend to drift into hypostatization, where abstract elements of the mathematical formalism are regarded as physically real without clear criteria for their physical existence.

The proposed approach consists of three steps. The first step is methodological: to define criteria against hypostatization and incorporate them into a realist position termed physical realism. The second step is ontological: to propose a monistic ontology—referred to as energism—that is appropriate for the quantum scale and to use it to motivate the concept of the Universal Energy Field (UEF) and quantum energy entities. The third step is formal, but deliberately limited in scope: an initial energistic dynamics is set out in order to show that the ontology can be given a disciplined mathematical expression without yet claiming a completed theory. The derivations therefore function chiefly as support for the ontological program.

2. Wave-Particle Duality as a Root Conceptual Source

Wave-particle duality asserts that quantum objects must be described as either wave–like or particle–like, depending on the context of measurement [5] [11] [15]. Historically, this duality arose as an extension of light's dual nature to matter, most notably in de Broglie's hypothesis and the subsequent development of wave mechanics. Early realist interpretations of the wave function regarded it as a physical wave that spreads out in space, but this perspective quickly conflicted with the discrete nature of detection events. The Copenhagen interpretation addressed this conflict by introducing the concept of wave function collapse and a measurement postulate that links the observer to the outcome [1] [12] [16].

From the perspective adopted here, the measurement problem is not merely an accidental addition to the formalism. Instead, it is a symptom of the dualistic starting point: if quantum objects are treated as particles when detected but as waves when they are propagating, one must explain how unitary wave-like evolution leads to single, localized outcomes. Different approaches, such as wave–function collapse, branching universes, hidden variables, and stochastic dynamics, can be seen as various strategies to address this initial conceptual divide [18] [22] [3] [9].

This paper therefore explores an alternative starting point: it suggests abandoning wave-particle duality as an ontological claim. Quantum objects are treated as single-category entities, where their extended structure accounts for interference, while their distinct interaction signatures explain the clicks registered by detectors. The remaining sections will elaborate on this approach within a realist framework that avoids hypostatization.

3. The Hypostatization Problem and Anti-Hypostatization Criteria

Quantum ontology is particularly vulnerable to hypostatization due to the highly abstract nature of its formalism. Realist approaches often elevate essential mathematical objects to ontological status. Wave-function realism [19] exemplifies this trend by treating the wave function as a physical entity, which is often defined within configuration space. Similarly, ontic structural realism [7] and information-theoretic realism [8] can follow a similar pattern by considering relations or information as fundamentally real.

The proposal here is not to dismiss mathematics but to regulate the transition from representation to ontology. Anti-hypostatization serves as a basic filter for ontological commitment. A candidate entity may only be regarded as physically real if it meets the following necessary, though not sufficient, conditions:

(i) Mind-independence: Its existence does not rely on agents, conventions, or representational frameworks;

(ii) Causal participation: It can, in principle, act and be acted upon in ways that influence physical outcomes;

(iii) Physical instantiation: It is instantiated in physical reality, typically through involvement in space and time or, more generally, through participation in the physically instantiated substratum that underlies spacetime.

4. Physical Realism: Definition and Scope

Physical realism is presented as a specific variant of scientific realism that focuses on the foundations of physics. It upholds three fundamental commitments typical of realism [4]: (a) there exists an objective, mind-independent physical reality; (b) this reality is, at least in part, knowable; and (c) the pursuit of explanation and understanding is a valid goal of physics.

What sets physical realism apart is its clear ontological discipline. The commitment to ontology is not applied arbitrarily; instead, it becomes unavoidable when seeking explanation, as explanation necessitates assertions about what exists. Physical realism therefore emphasizes that ontologies must be stated explicitly and constrained by the anti-hypostatization criteria. Following the primitive-ontology approach [2], it is preferable to clarify ontology early in the process, rather than retrofitting it to a mathematical model that has already proven successful, as retrofitting can lead to hypostatization.

Physical realism allows for significant mathematical abstraction during modeling but rejects the idea that mere mathematical success justifies an increase in ontological claims [17]. When the goal is explanation, the ontology must be physically instantiated. The remainder of this paper will explore which ontology can reasonably support a non-dualistic quantum foundations program, while adhering to these constraints.

5. A Proposed Ontology: Energy, the Universal Energy Field, and Quantum Energy Entities

5.1 Ontological Motivation from Matter-Energy Interconvertibility. Contemporary physics reveals a profound interconvertibility between mass and energy [13] [14] [20]. This understanding encourages an ontological interpretation: if what is typically considered "substance" (matter) can be transformed into energy and vice versa, then energy becomes a strong candidate for an ontological description at micro-scales. The current perspective is monistic, meaning that there is a single underlying substance, but different descriptions become appropriate at different scales. At macroscopic scales, "matter" remains a stable and practical description; at quantum scales, an energy-based description is more fitting.

5.2 Inference to a Universal Energy Field. If energy is viewed as a physically instantiated substratum, the question arises: what serves as the continuous basis on which energetic structures are instantiated? The Universal Energy Field (UEF) is introduced as a conceptual hypothesis: a pre-spatiotemporal energetic substratum that underlies spacetime and supports structured energetic configurations. The UEF is not a quantum field theory (QFT) field among others, and this paper does not provide its governing equations. Instead, it functions as an ontological foundation for energistic instantiation.

5.3 Quantum Energy Entities. Quantum objects are modeled as energy waveforms: extended, coherent, indivisible energetic configurations embedded in the UEF. Interference and diffraction illustrate their extended structure, while discrete detection events reflect quantized energy transfer during interactions. In this manner, the framework seeks to replace the dualistic wave-particle picture with a single-category ontology.

5.4 Ether Objection (Conceptual). Since the UEF is a universal substratum, an immediate objection arises that it revives the concept of ether. The conceptual response is that classical ether theories proposed a medium that fills spacetime, with mechanical properties and a preferred rest frame. In contrast, the UEF is defined as pre-spatiotemporal and therefore cannot define motion relative to itself within spacetime.

In Appendix A, an attempt is made to preliminarily describe the UEF and energy wave-form concepts using mathematical formalism, in the form of an initial nonlinear UEF equation and the corresponding stationary equation for generic condensed energy entities.

6. Meta-Analysis: Conceptual Reinterpretation of Selected Quantum Phenomena

This section outlines, at a conceptual level, how the proposed ontology can reinterpret several well-known phenomena that motivate competing interpretations.

6.1 Measurement and Localization. Measurement is understood as a physical interaction: an irreversible transfer of energy that produces a stable macroscopic record. Consequently, localization is seen as dependent on interactions rather than being an intrinsic property of quantum objects. There is no need for a physical collapse postulate; the wave function remains a representational tool for tracking energetic evolution and the possibilities for interaction.

6.2 Double-Slit Interference. In this view, an energy wave-form has a real spatial extension. Its interaction with both slits reflects this extension and results in an interference pattern. The discrete impacts observed on the screen can be explained by quantized energy transfer during localized interaction events.

6.3 Compton Scattering. The discreteness seen in Compton scattering is interpreted as a quantized exchange of energy and momentum between energetic wave-forms, rather than as evidence that the photon must be considered a classical particle. This framework thus treats Compton results as compatible with a wave-form ontology.

6.4 Entanglement. Entangled systems are understood as a single extended energetic structure within the Universal Energy Field (UEF), rather than as spatially separate objects connected by superluminal influence. The correlations observed are attributed to energistic unity ("wave integrity") rather than to signal-mediated action occurring at a distance.

These reinterpretations are conditional and programmatic. Their purpose is to demonstrate conceptual coherence with the experimental characteristics of quantum phenomena, rather than to replace the standard mathematical formalism.

7. Underdetermination under Ontological Discipline

Underdetermination is frequently understood to imply that ontology in quantum mechanics is optional or merely a matter of convention. It is also regarded as one of the significant challenges to scientific realism [4] [6]. However, physical realism offers a different perspective. Interpretive plurality increases when abstract formal elements are freely reified; different camps reify different parts of the same formalism, thus generating incompatible ontologies without new empirical content. The principle of anti-hypostatization restricts the range of acceptable ontologies: permissible ontologies must be physically instantiated and mind-independent. Consequently, underdetermination becomes conditional rather than unrestricted. Competing ontologies may remain viable, but only within the limited class that meets the criteria of physical realism. The ontology proposed here is presented as one such candidate.

8. Comparative Analysis

Feature	**Copenhagen**	**Bohmian**	**Many-Worlds**	**GRW**	**Structural / information**	**UEF approach**
Primary ontology	Minimal / agnostic	Particles (+ law)	Branching wave	Matter density / flashes	Structures / information	Energy wave-forms in UEF
Wave function status	Instrumental / epistemic	Nomological / varies	Ontic	Ontic	Structural / informational	Representational
Measurement	Observer-linked	Dynamics	Branching	Objective collapse	Contextual	Energy-transfer interaction
Duality	Retained	Retained	Retained	Retained	Reframed	Abandoned (single category)
Nonlocality	Problematic	Guidance nonlocal	Global state	Stochastic dynamics	Relational	Energetic unity
Status here	Interpretation	Full theory	Full theory	Full theory	Stance	Ontology-led research program

Table 1. UEF-based approach versus selected quantum interpretations (conceptual comparison).

Feature	Instrumentalism	Scientific realism	Wave-function realism	Structural / information realism	Physical realism
Mind-independent reality	No commitment	Yes	Yes	Often structural	Yes
Ontology for explanation	No	Often implicit	Strong (wave function)	Abstract structures / information	Explicit and instantiated
Attitude to abstracta	Free use	Mixed	Abstracta reified	Abstracta privileged	Anti-hypostatization filter
Methodological focus	Prediction	Truth / approximate truth	Wave-function ontology	Structure / information	Explanation with ontological discipline

Table 2. Physical realism versus major philosophical stances (ontology and method).

9. Results and Discussion: Contributions, Limitations and Future Work

At this stage, the main contributions of the paper are to (i) reorganize the explanatory priorities of quantum foundations by recognizing wave-particle duality as a fundamental source of several conceptual challenges; (ii) offer a structured realist framework (physical realism) that is safeguarded against hypostatization; (iii) outline the UEF and energy wave-forms as a coherent ontological research program that aligns with the experimental nature of quantum phenomena at the conceptual level; and (iv) provide a disciplined initial UEF dynamics, together with an explicit route from a primordial UEF regime to the condensation of generic stable energy entities.

The paper remains chiefly ontological in emphasis, and the formalization presented in Appendix A is therefore intentionally limited to an initial stage. Specifically, it does not provide a full endogenous dynamics for χ or a proof of existence and stability for all condensed solutions of the stationary equation. However, the paper now combines a disciplined ontology with an initial formal analogue-model that reaches the equation for generic condensed energy entities. The next tasks are therefore clear: to sharpen the dynamics of χ, to study existence and stability regions for condensed solutions, to develop internal mode structure for specific species, and to understand how radiative disturbances and spacetime geometry arise from the underlying energistic organization.

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Appendix A

Primitive Postulates and Initial UEF Equations up to Generic Energy Entities

Introduction

The purpose of this formalization attempt is to show that the energistic ontology can support a disciplined initial dynamics, together with an explicit route from a primordial UEF regime to the condensation of generic stable energy entities. To this end, it aims to formalize the earliest stage of the program: a relational, pre-spatiotemporal dynamics capable of supporting generic condensed formations.

Two clarifications are central from the start. First, the mathematical formalism is an analogue-model, not yet a final fundamental theory. Second, the primitive quantities introduced below must not be read through ordinary spacetime-based intuitions without reservation.

Scope, methodological stance, and explicit disclaimers

The formalism should be read as the first workable analogue of primitive succession and condensation, not as a completed derivation of emergent spacetime structure.

In the equations below, the parameter λ plays the formal role of an evolution variable. In that purely mathematical sense it functions like time. However, it is not identified with emergent physical time t. Rather, λ orders primitive succession within the formal model. The present paper leaves open whether the later relation between λ and t is one-to-one, many-to-one, coarse-grained, or state-dependent.

The regime parameter χ is also treated with restraint. Although the motivating cosmological picture suggests that χ varies across primordial evolution, the derivations below are carried out at fixed χ. Accordingly, χ is used here as an effective frozen or adiabatic control parameter. A later theory should endogenize χ by making it a functional of the global UEF state or by giving it an independent equation of motion.

Because the primitive dynamics is nonlinear, the resulting structures do not satisfy ordinary linear superposition at the fundamental level. If familiar quantum superposition is later recovered, it must arise as an emergent feature of a later regime, not as a primitive axiom of the present model.

Primitive terminology and anti-hypostatization

The formal symbols introduced in this paper are not interpreted in ordinary spacetime terms. The variable Ψ_i is not a field amplitude over spacetime points. It denotes a primitive UEF state component attached to the i-th differentiation of the energistic substratum. Likewise, ω_λ is not a physical frequency in time, but a stationary-mode parameter with respect to λ. At this level, terms such as amplitude, frequency, oscillation, and localization must be used with care and, when necessary, read in a restricted sense.

The anti-hypostatization requirement remains in force. The primitive units indexed by i, j, ... are not independently existing abstract objects. They are formal representatives of real, mind-independent differentiations within the energistic substratum itself. The graph, matrix, and index language belong to the representation; the ontological referent remains the UEF alone.

Primitive postulates

The formal proposal is based on six postulates.

Postulate 1. Ontological monism. There exists a single fundamental physical substratum, the Universal Energy Field. All physically real formations in the present framework are modes, differentiations, or organized structures of that substratum.

Postulate 2. Pre-spatiotemporal priority. The UEF is ontologically prior to spacetime. Its primitive dynamics is therefore not stated on a pre-given manifold equipped with spatial and temporal coordinates.

Postulate 3. Primitive differentiations. The UEF possesses real internal differentiations. In the formalism these are indexed by primitive units, but those units are not independent entities. They are formal representatives of real aspects of the energistic substratum.

Postulate 4. Primitive succession. The UEF is intrinsically dynamical. Its primitive succession is parameterized by λ, which is not identified with physical time but serves as a formal ordering parameter in the present model.

Postulate 5. Regime dependence. The UEF may occupy different primitive regimes characterized by a parameter χ. Stable organized formations need not exist for all χ. In the present paper χ is treated adiabatically, that is, as fixed during the local derivation.

Postulate 6. Condensation threshold. Generic stable energy entities become dynamically favored when χ enters a stability domain below the relevant critical threshold. In the opposite direction, when χ leaves that domain, destabilization or evaporation of previously stable formations may occur.

The above postulates above state only the minimum needed for a first formal stage. In particular, the condensation process is expressed in terms of a threshold: the key issue is not merely the rate at which χ changes, but whether χ lies inside or outside the stability domain for condensed formations.

Primitive relational structure and admissible states

Let *I* be an index set carrying a primitive relational graph structure G = (I, E). At the present stage this graph is not interpreted geometrically. Its role is to encode primitive adjacency or relational nearness. The most natural working choice is to let the support of the coupling matrix define the graph: two indices *i* and *j* are adjacent when K_{ij} is nonzero, or more generally when it exceeds a chosen relational threshold.

The UEF state at primitive succession parameter λ is represented by a family $\{\Psi_i(\lambda)\}$_(i∈I). For mathematical control, admissible configurations are taken to lie in a finite-action class; in the simplest case one may require $\Psi(\lambda) \in \ell^2(I)$ for each admissible λ. This is the discrete analogue of imposing square-integrability or finite-energy conditions in ordinary field theory.

The topological language used later is now fixed. A formation is said to be localized in the primitive sense when its support is concentrated on a connected bounded subgraph, or on an effectively bounded relational neighborhood, of G. Accordingly, extension at the primitive level is topological rather than geometric. What later appears as geometric extension is, at this stage, only relational extension.

Initial UEF dynamical framework

Assume that the coupling matrix $K_{ij}(\chi)$ is Hermitian. In the simplest real case this reduces to symmetry: $K_{ij}(\chi) = K_{ji}(\chi)$. Assume further that the nonlinear potential is site-local, so that it depends on $|\Psi_i|^2$ at each primitive unit and contains no cross-site nonlinear terms. Finally, variations are taken to vanish at the endpoints of the λ-interval, so boundary terms from integration by parts are dropped in the usual way.

Under these assumptions, a minimal action for the first-stage analogue-model is

$$S[\Psi, \Psi^*, \chi] = \int d\lambda \, [\sum_i |d\Psi_i/d\lambda|^2 - \sum_{i,j} \Psi_i^* K_{ij}(\chi)\, \Psi_j - \sum_i V(|\Psi_i|^2; \chi)] \quad (1)$$

where $V(|\Psi_i|^2; \chi)$ is a site-local self-interaction potential. A standard illustrative choice is the so-called cubic-quintic equation-of-motion form, corresponding to a quartic-sextic potential in the amplitude variable:

$$V(|\Psi_i|^2;\chi) = (a(\chi)/2)|\Psi_i|^4 + (b(\chi)/3)|\Psi_i|^6 \quad (2)$$

Varying the action with respect to Ψ_i^*, while holding χ fixed and using endpoint conditions that kill boundary terms, yields

$$d^2\Psi_i/d\lambda^2 + \sum_j K_{ij}(\chi)\Psi_j + \partial V/\partial\Psi_i^* = 0 \quad (3)$$

Because V depends only on $|\Psi_i|^2$, this becomes

$$d^2\Psi_i/d\lambda^2 + \sum_j K_{ij}(\chi)\Psi_j + V'(|\Psi_i|^2;\chi)\,\Psi_i = 0 \quad (4)$$

This is the initial UEF dynamical equation proposed in the present first-stage model. It is not a spacetime field equation. It is a primitive relational evolution law written for indexed differentiations of the substratum.

Condensation threshold and generic energy entities

On cosmological considerations, it is assumed the existence of a critical χ threshold or stability domain. When χ remains above that threshold, stable condensed formations are absent or disfavored. When χ enters the stability domain below the threshold, stable formations become dynamically possible. The present paper does not yet derive the full nonequilibrium transition by which solutions flow from a high-χ regime to a condensed regime. It isolates instead the quasi-static entity equation valid at a fixed χ within that domain.

To look for candidate condensed formations, adopt the stationary-mode ansatz

$$\Psi_i(\lambda) = exp(-\,i\,\omega_\lambda\,\lambda)\,\varphi_i \quad (5)$$

with $\omega_\lambda \in \mathbb{R}$ so that $|\Psi_i|^2 = |\varphi_i|^2$ is independent of λ. Substitution into the primitive equation gives

$$-\,\omega_{\lambda^2}\,\varphi_i + \sum_j K_{ij}(\chi)\,\varphi_j + V'(|\varphi_i|^2;\chi)\,\varphi_i = 0 \quad (6)$$

This is the generic stationary equation for condensed energy entities. A nontrivial solution $\{\varphi_i\}$ counts as a candidate energy entity only if at least four conditions are met:

- Nontriviality: the solution is not identically zero.

- Primitive localization: its support is concentrated on a connected bounded, or effectively bounded, region of the relational graph induced by K_{ij}.

- Persistence: it is stable or metastable under admissible perturbations in the regime considered.

- Bounded primitive action or energy functional: the relevant action-derived functional remains finite for the solution class under consideration.

With the quartic-sextic potential above, we have

$$V'(|\varphi_i|^2;\chi) = a(\chi)|\varphi_i|^2 + b(\chi)|\varphi_i|^4 \quad (7)$$

and therefore

$$-\,\omega_{\lambda^2}\,\varphi_i + \sum_j K_{ij}(\chi)\,\varphi_j + a(\chi)|\varphi_i|^2\,\varphi_i + b(\chi)|\varphi_i|^4\,\varphi_i = 0 \quad (8)$$

Although no full existence theorem is supplied here, the expected qualitative regime is clear. One seeks a balance in which the coupling structure supports relational spreading, the lower-order nonlinear term provides self-focusing, and the higher-order term prevents uncontrolled blow-up. This is enough to motivate the search for bounded localized solutions in later mathematical work.

On λ, χ, and the limits of the present formalism

It is accepted that λ plays the formal role of a one-parameter evolution variable. In that respect the present construction is structurally analogous to a one-dimensional nonlinear lattice dynamics. It is only claimed that such a formal analogue can model primitive succession without yet identifying it with emergent physical time. The same applies to χ. In this initial formalization, χ is not yet endogenized. It is used as an effective control parameter that labels primitive regimes and lets one formulate a threshold picture of condensation. A deeper version of the formalism should replace this by either χ = χ[Ψ], that is, a collective functional of the global UEF state, or by a coupled equation of motion for χ itself.

Because the primitive dynamics is nonlinear, two stationary entities cannot in general be added linearly to obtain a two-entity state. The present model therefore does not claim that familiar Hilbert-space structure is fundamental. At most, such structure might appear effectively in a later regime.