Quantum Potentiality: An Aristotelian Interpretation of Modern Physics

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Abstract

Quantum theory is among the most successful scientific theories in the history of physics. Predicts the outcomes of physical experiments with extraordinary precision, has enabled the development of modern technologies, and forms the foundation of contemporary microphysics science. Despite its empirical success for over a century, quantum mechanics continues to lack a unified and ontologically coherent interpretation. Although its mathematical formalism is rigorously formulated and exceptionally successful in predicting experimental results, there remains profound disagreement about the nature of the reality that quantum theory describes, particularly from an ontological perspective. This article argues that Aristotelian concepts of form, potentiality, and actuality provide a coherent ontological framework for understanding key quantum phenomena, such as superposition, the wave function, and its collapse, without recourse to epistemological idealism, many-world interpretations, or ad hoc metaphysical constructs. Moreover, this approach not only addresses foundational interpretative issues within quantum mechanics but also reconnects the theory with the broader ontological tradition of Aristotelian metaphysics. By doing so, it opens the way toward a unified metaphysical vision in which modern physics and classical philosophical categories are brought into mutual intelligibility. The Aristotelian ontology offers a natural way to understand the quantum state as a mode of being, a reality existing in potentiality, becoming actual upon measurement, without denying the genuine ontological status of potentiality itself. From this perspective, quantum theory no longer appears ontologically paradoxical, but instead emerges as a challenge to rethink the very foundations of what we consider to be real. Aristotelian ontology proves to be so naturally aligned with the ontological demands

of quantum theory that it requires no ad hoc constructions or revisions. Rather than departing from Aristotle's original insights, I find that they can be fully and fruitfully applied, without distortion, to the most perplexing phenomena of modern physics. Moreover, the Aristotelian approach enables us to interpret some paradoxes that appear only as a consequence of ontological reductionism, not as failures of understanding or imagination.

Aims of the Paper

This paper pursues four central goals, each of which contributes to a deeper metaphysical and interpretive understanding of quantum theory through the lens of Aristotelian ontology.

1. **To restore the ontological reality of potentiality:** In contrast to many interpretations of quantum mechanics that treat potentiality merely as an ad hoc construct, understood as a convenient explanatory device lacking deeper ontological grounding, this article argues that potentiality (*dynamis*, from Greek *δυάμισ*) should be seen as a genuine mode of being. Quantum states are interpreted here not as placeholders for future measurements or as pragmatic tools, but as structured potencies intrinsically directed toward actualization. Therefore, the work explicitly distinguishes between two autonomous modes of being: BEING IN ACT and BEING IN POTENCY.

2. **To offer a unifying framework across interpretations:** By showing that the Aristotelian distinction between potentiality and actuality lies at the heart of the interpretive tensions among various approaches (Copenhagen, Everett, GRW, etc.), this paper uncovers a deeper structural unity. The proposed metaphysical framework enables us to reinterpret these competing models not as mutually exclusive theories, but as attempts to articulate the ontological transition from potency to act.

3. **To reintroduce ontology into scientific discourse:** This paper challenges the widespread assumption that science can proceed without ontological commitments. It argues that every interpretation of quantum theory necessarily presupposes an account of being, often implicitly. Despite its ancient origin, Aristotelian ontology is presented not as a regression but as a rigorous and coherent foundation, offering a natural and intelligible way to make these metaphysical commitments explicit and philosophically grounded.

4. **To invite a philosophical rethinking of physical reality:** Beyond its technical and theoretical aspects, this paper addresses a broader philosophical need: to reconsider the very meaning of being in light of quantum mechanics. Rather than explaining away the counterintuitive aspects of quantum phenomena, it invites a broadening of our conception of reality itself, guided by an Aristotelian ontology that embraces not only what is BEING IN ACT, but also what is BEING IN POTENCY - acknowledging as an inseparable part of reality not merely what is fully actualized, but also what can be, and presently exists as BEING IN POTENCY.

Contents

1 Introduction

In the field of quantum mechanics, the following questions continue to emerge with persistent urgency: What is a quantum state? Is it something real, or is it merely a tool for predicting probabilities? What exactly *collapses* during measurement? What ontological status should we ascribe to a virtual particle or to the pervasive phenomenon of nonlocality in quantum theory [Kulhanek, 2024]?

Is nonlocality introduced merely as a consequence of insurmountable epistemic limitations, boundaries beyond which our capacity for knowledge, constrained by experimental means, cannot reach? Or does nonlocality, instead of signaling the limits of human knowledge, constitute an ontologically autonomous aspect of reality itself, one that we rightly recognize as indeterminate and nonlocal in its being?

In response to such questions, a wide range of interpretations of quantum mechanics have emerged, each differing primarily in how they assign ontological status to various mathematical objects, such as the wave function, quantum states, virtual particles, or the act of measurement itself. Some interpretations (e.g., the Copenhagen interpretation) adopt what might be called an epistemological approach, focusing on predictive utility rather than ontological description, while others (e.g., the de Broglie–Bohm theory or spontaneous collapse models like GRW) attempt to capture the ontological structure of quantum reality, sometimes at the cost of introducing ad hoc elements into the interpretive framework.

This ontological ambiguity becomes especially evident in attempts to unify quantum theory with general relativity. Since the second half of the 20th century, physics has been driven by the search for a *Theory of Everything* that would describe all known interactions within a single framework, from quantum processes at the level of elementary particles to the cosmological dynamics of the universe as a whole [Weinberg, 1992, Penrose, 2004]. However, this ambition runs up against a deep ontological discord between the two pillars of modern physics: whereas quantum theory operates with the probabilistic dynamics of quantum fields, in which physical objects exist in a state of oscillation between possibility and actualization, general relativity describes space and time as a continuous geometrical structure whose curvature is determined by the distribution of matter and energy, without regard for the various modalities in which these entities might exist.

These two physical theories thus rest on fundamentally different ontological premises, not only in terms of mathematical formalism but more importantly in terms of what they consider to be the basic constituents of "physical reality", that is, what is truly existent. It is therefore unsurprising that previous attempts at unification – including string theory and loop quantum gravity – have encountered major conceptual difficulties [Rovelli, 2004, Smolin, 2006, Maudlin, 2019]. The result is a situation in which both physical theories function within separate domains, while their ontological, and therefore physical, unification remains elusive.

1.1 The Necessity of Aristotelian Ontology for Modern Physics

This work therefore aims to demonstrate that Aristotle's doctrine of being – as formulated in Physics [Aristotle, 1957] and Metaphysics [Aristotle, 1933] - is not only a historical and now outdated stage in the development of thought on the path to modern science, but rather a framework that can shed light on some of the most pressing problems in contemporary physics. The Aristotle ontology does not appear as a 2,500-year-old archaic[1], and obsolete construction devised in an era of insufficient empirical knowledge, but rather as a testament to the possibility of building a deep and lasting ontology grounded in reason and first principles.

As will be shown in what follows, it is striking that the true significance of Aristotelian ontology is not most clearly revealed in the observation of what we now call the macroscopic world, the world as Aristotle could directly perceive it, but rather in the investigation of the microscopic realm: the world of subatomic particles and quantum phenomena, of which Aristotle could not have had any empirical knowledge.

Yet, he constructed an ontology whose hidden precision, metaphysical depth, and universality are only now beginning to manifest themselves, particularly in light of the interpretive difficulties posed by quantum theory. Concepts such as potentiality and actuality, long relegated to the margins of scientific discourse, may offer the most coherent metaphysical key to understanding quantum superposition, the collapse of the wave function, and the probabilistic structure of

[1] Many contemporary physicists tend to construct empirically conditioned ontologies, often motivated by the attempt to explain specific phenomena of quantum mechanics. At the same time, numerous philosophical approaches conceive the relationship between ontology and empirical knowledge more loosely, emphasizing the primacy of first principles. As a result, ontology grounded in irreducible foundations and contemporary physics remain in a state of mutual non-convergence, one that continues to hinder the possibility of a truly fruitful dialogue between physics and metaphysics.

measurement. In this sense, it is not modern physics that retroactively confirms Aristotle, but rather Aristotle, who anticipates the ontological demands of modern physics more accurately than many contemporary frameworks.

This paper therefore proposes the idea that the deeper our empirical understanding of the world becomes, the more timely and indispensable Aristotle's ontology becomes, specifically due to its completeness and foundation in the first principles[2]. It appears that wherever modern physics has moved beyond the deterministic and commutative framework, it must also move beyond the metaphysical reductionism upon which that framework was built.

2 Some Contemporary Interpretations of Quantum Mechanics

Quantum mechanics does not possess a single consensual interpretation but rather a spectrum of interpretative frameworks that differ fundamentally in their ontological assumptions. These interpretations are not merely philosophical commentaries on the same physical theory—they often represent profoundly different conceptions of what *exists in the world*, what it means *to be* and what forms the basis of physical reality. What one interpretation considers to be real, another may regard as a mere computational tool or even as a subjective state of the experimenter's mind.

This plurality is not a sign of interpretive richness, but rather a consequence of an unresolved ontological foundation from which the various interpretations of quantum theory arise. The aim of this chapter is therefore to briefly present the most influential interpretations of quantum mechanics and to outline their respective approaches to ontology. The aim is not to explain what the physical theory states in physical and quantitative terms but to offer a fundamental ontological reflection on what each interpretation implies about being. Detailed discussions of individual theories are neither possible nor necessary here; the reader is referred to the relevant scholarly literature.

[2]The difficulty in understanding most interpretations of quantum mechanics is often attributed to a supposed deficiency in human imagination—allegedly rooted in the lack of direct experiential access to the reality of the microscopic world. However, this work takes the opposite position: the problem is not in an imagination constrained by the senses, but in a weakness inherent to the interpretations themselves, that is, in the inadequacy of the ontological framework within which quantum phenomena are interpreted.

2.1 The Copenhagen Interpretation

The Copenhagen interpretation of quantum mechanics is the oldest and, for a long time, the most influential interpretation of quantum theory, mainly associated with Niels Bohr and Werner Heisenberg [Heisenberg, 1958]. This interpretation treats the wave function not as an expression of what is, but as a tool for determining what can be expected with a certain probability. In other words, it does not represent any objectively existing state of a physical system, but only information about the expected measurement outcome.

This view is shaped by a pragmatic and instrumental conception of scientific theories, according to which scientific models are not necessarily meant to describe *the reality itself*, but rather to serve as tools to effectively predict empirical data. The Copenhagen interpretation, accordingly, does not aim to explain what the world is but rather what can be observed. However, this ontological restraint does not entail ontological neutrality; on the contrary, its underlying assumptions carry far-reaching implications for what is to be considered real. The Copenhagen interpretation does not escape the consequences of reductionist conceptuality.

Reality itself, in Copenhagen interpretation, is codetermined by the act of measurement - this is the role of the concepts of complementarity and wave function collapse - which denote the transition from indeterminacy to a definite result. The wave function remains in a superposition of possible states until the measurement *selects* one of these states, and thus makes it real. In this framework, what exists is only what has been measured, that is, what has (or retroactively had) a probability of 1. Realization becomes the criterion of being: What is merely potential or probabilistic (less than 1) is not regarded real.

Copenhagen interpretation thus ontologically inclines toward the so-called actualism, a metaphysical position which holds that only what is currently actual also truly exists. Anything not actualized through measurement (or through some other act) remains outside the domain of a real being. In this sense, the Copenhagen interpretation may appear similar to epistemological idealism, which posits that reality is dependent on the consciousness of the subject. However, there is a crucial distinction: while idealism makes the subject the constitutive source of being, the one who *grants* existence, actualism regards being not as a product of consciousness, but as the result of interaction. Reality is not constituted by the mind, but actualized through the act of observation. Thus, in the *actualist* reading of Copenhagen, the observer does not create reality ex nihilo but serves as a condition under which latent possibilities are realized. Reality, then, is not passively constituted by a knowing subject but actively unfolds through relational events in which potentialities become actual.

The result of the interpretation is that the potential layer of being, which is essential for quantum description, is not ascribed explicit or even implicit ontological status. The world described by the Copenhagen interpretation consists only of actualized phenomena (BEING IN ACT); what has not been measured is considered *unactualized* and, therefore, nonexistent. Thus, this interpretation implicitly denies the ontological status of potentiality (BEING IN POTENCY). Although it does not state this explicitly, its implications lead to a severely reduced concept of being: one in which reality exists only insofar as it has been conclusively observed.

This work proposes that BEING IN POTENCY could be understood as a fully real and coequal mode of being within the Aristotelian metaphysical framework, not less real than BEING IN ACT, that is, the mode of being corresponding to a fully actualized state, such as a measured quantum outcome with probability one. To clearly articulate this distinction, the terms BEING IN ACT and BEING IN POTENCY will be used throughout this document. Whereas BEING IN ACT denotes that which has been fully realized in accordance with its form, BEING IN POTENCY refers to that which exists as a structured potency directed toward realization but not yet actualized. Both modes are ontologically grounded and irreducible to one another. By reintegrating BEING IN POTENCY into the structure of being, this work lays the foundation for a metaphysical reconstruction in which quantum phenomena, such as superposition, measurement, and collapse, can be interpreted not as paradoxes or epistemic gaps, but as natural expressions of a reality that includes what is and what can be. This ontological reconfiguration carries far-reaching implications not only for the interpretation of quantum mechanics but also for the broader philosophical understanding of what it means to be.

2.2 The Many-Worlds Interpretation

The Many-Worlds interpretation [DeWitt and Graham, 1973], a realist and unitary framework, rejects the notion of wave function collapse altogether. According to Hugh Everett III, measurement does not select a single outcome as reality; rather, all possible outcomes of a quantum event are realized, each in a separate *branch* of the universe. Every measurement, within this interpretation, leads to a branching of reality into parallel worlds, with each branch corresponding to a different actualization of the possible outcomes. In place of one realized actuality, we are presented with a multiplicity of simultaneously existing actualities.

Everett thus preserves the unitary evolution of the wave function without sudden collapse, thereby maintaining the mathematical consistency of quantum theory. However, the ontological cost of this step is high: it involves postulating the real existence of an infinite number of parallel universes, each corresponding to a different measurement outcome, that are completely disconnected from one another and, in principle, **empirically inaccessible**.

From an ontological point of view, this model is remarkable. Each quantum possibility is considered as BEING IN ACT, and BEING IN POTENCY is entirely absent. Everything that is quantum-mechanically possible is therefore simultaneously real, albeit in a different branch. The Everett interpretation thus rejects the very concept of potentiality as a valid ontological level of being: possibility does not exist here, only actuality, in various dimensions of the multiverse.

In this respect, the many-worlds interpretation radically diverges from Aristotelian ontology, which recognizes a fundamental distinction between what is in potency and what is in act. Whereas Aristotle understands potentiality as being on the way to realization as a mode of being that is real but incomplete, Everett abolishes this ontological distinction by asserting that each possibility is realized immediately in its own branch. Instead of one reality and many possibilities, we get an infinity of realities and no possibility.

This also reveals that even this interpretation, despite its formal restraint, assumes a very specific ontology, one that closely resembles metaphysical actualism in its extreme form: everything that can exist does exist simultaneously, though (apparently) beyond mutual reach.

In the following chapters, this work will attempt to show that such a conception not only loses the ability to explain the difference between possibility and realization but also, above all, lacks a conceptual tool for grasping the quantum phenomenon as something *on the way to actualization*. In this respect, the Aristotelian concept of potentiality may be not only an alternative but also a more ontologically economical path to understanding reality, without the need to postulate an infinite number of actual worlds.

2.3 The de Broglie–Bohm Theory (Pilot-Wave Theory)

The de Broglie-Bohm theory (pilot wave theory) represents a deterministic and realist interpretation of quantum mechanics [Holland, 1993], in which particles follow clearly defined trajectories. These trajectories are not random but are guided by the so-called pilot wave. The pilot wave evolves according to the Schrödinger equation and influences the motion of particles by determining how they move through space.

A key feature of this theory is that particles have precisely defined positions at every moment, which makes it distinct from the standard quantum-mechanical description that operates with probabilities. In this way, it retains the classical notion that objects exist objectively in space and time with clearly delineated properties. According to this theory, every particle exists as BEING IN ACT at all times.

An important characteristic of the de Broglie–Bohm theory is its non-locality. This means that the behavior of a particle can instantaneously depend on the configuration of the system at other distant locations in space. This nonlocality is *hidden*; although not directly observable in the usual sense, it is essential for the proper functioning of this interpretation.

Summary of key points of the theory:

- The particles follow deterministic trajectories guided by the pilot wave.
- The pilot wave evolves according to the Schrödinger equation.
- Particles always have clearly defined positions (realism).
- The theory is non-local, meaning that a particle can be influenced instantly by distant events.

2.4 The GRW Theory - Spontaneous Collapse Theory

GRW theory, proposed by Ghirardi, Rimini, and Weber, modifies standard quantum mechanics by turning the collapse of the wave function into a physical process, rather than simply an epistemological update [Bassi et al., 2013]. According to this interpretation, the wave function undergoes a spontaneous collapse as a real physical event. This collapse is relatively rare for individual particles but becomes frequent for macroscopic objects, which explains why quantum effects are not observed at the level of everyday reality.

Ontologically speaking, the GRW theory introduces a new dynamical law that explicitly describes when and how the wave function collapses. In this theory, the collapse is understood as an objective ontological transition from a superposition to a definite state, thereby distinguishing itself from interpretations in which the collapse is merely a result of knowledge or measurement. The GRW theory thus unequivocally asserts that the world truly exists in definite states, which are realized through a physically defined collapse process.

Summary of key points of the GRW theory:

- The collapse of the wave function is a real physical process.
- Spontaneous collapse occurs rarely for individual particles, but becomes frequent for macroscopic objects.
- Introduces a new dynamical law that determines how the wave function changes.
- The ontological transition between superposition and one of the possible states is an objective reality.

2.5 QBism - Quantum Bayesianism

QBism (Quantum Bayesianism) is a modern instrumentalist interpretation of quantum mechanics that fundamentally redefines the role and meaning of the wave function [von Baeyer, 2016]. In this approach, the wave function is not regarded as an objective description of physical reality but rather as a subjective expression of belief, a probabilistic estimate made by an individual agent on the results of future measurements.

The central feature of QBism is its explicit rejection of any ontological ambition. Quantum mechanics, from this perspective, is not a theory of what the world *is*, but a personal tool that allows an agent to manage expectations and update beliefs based on experimental results. The act of measurement is not understood as an interaction with an external world that reveals preexisting properties but as an event that prompts the agent to revise their internal web of expectations.

Consequently, QBism shifts the focus of quantum theory entirely onto the personal experience of the observer. The wave function thus becomes a purely subjective artifact, useful for organizing and updating an individual's beliefs, but devoid of any ontological status independent of the observer. The external world, while presupposed in practice, is ontologically silent within the framework of quantum bipolarism: quantum theory is concerned solely with the agent's experiences, not with the objective structure of reality.

While QBism offers a coherent framework for avoiding certain interpretative paradoxes by sidestepping questions about independent reality, it does so at the cost of abandoning the traditional ambition of physics to describe the world as it is, independent of individual observers. In this respect, QBism marks a decisive departure from both classical realism and any metaphysics that aspires to a comprehensive account of being.

From the perspective of Aristotelian ontology, QBism does not offer a genuine metaphysical account of being. Rather, it confines itself to the epistemic sphere of subjective beliefs, thus abandoning the traditional aspiration of physics to describe a mind-independent reality. In doing so, it undermines the very possibility of ontology as a study of being as such.

Summary of key points of QBism:

- The wave function is a subjective expression of an individual agent's belief about future measurement outcomes.
- Quantum mechanics serves as a personal tool for updating expectations, not as an ontological description of the world.
- Measurement is an event that updates the agent's internal beliefs, not an objective interaction with a mind-independent reality.
- The ontological structure of physical reality lies beyond the scope of the theory and remains unaddressed within QBism.

2.6 Consistent Histories and Ontological Restraint

The theory of consistent histories, originally proposed by Robert Griffiths and further developed by Murray Gell-Mann and James Hartle, offers an interpretation of quantum mechanics in which properties can be attributed to quantum systems even without the act of measurement [Griffiths, 2002]. The key concept here is the so-called consistent (or decoherent) set of histories, that is, a sequence of projection operators that preserves internal logical coherence.

In this interpretation, measurement does not play a special ontological role. Instead, any statement about the system is based on whether the corresponding history is part of a consistent set. Quantum mechanics, through this approach, becomes a theory of the probabilities of different histories, with the key criterion being their mutual decoherence (lack of interference).

Ontologically, however, the theory of consistent histories remains neutral and limited. It does not seek to describe what truly exists but confines itself to ensuring the internal coherence of possible sequences of events. It thus trades ontological explanation for formal consistency, focusing on the mathematical organization of histories rather than the metaphysical nature of being.

Summary of key points of the consistent histories theory:

- It allows for the description of a system even without the act of measurement.
- Its foundation lies in consistent (decoherent) sets of histories.
- Measurement is not a special category, but one type of history.
- Ontologically, the theory remains neutral and focuses on formal consistency.

2.7 Modal Interpretations

Modal interpretations, developed in various versions by authors such as Olimpia Lombardi and Dennis Dieks, represent a specific approach to quantum mechanics in which part of the quantum system is considered to be actual even without the act of measurement. The central theme is the distinction between what is actual (realized) and what is merely potential (possible), both being considered part of the system's descriptive structure.

In these interpretations, the wave function is not a complete description of reality but rather a tool that allows us to determine which properties of the system are currently actual and which remain only in the potential mode. The wave function thus serves as a determination of a modal space of properties: those that are presently realized and those that are merely possible.

Modal interpretations thus constitute a partial acknowledgment of the potential structure of the world within the framework of quantum theory. However, they typically understand potentiality only functionally, as a way of organizing different property attributions, rather than ontologically, as a genuine mode of being. Unlike Aristotelian metaphysics, they do not operate with a deeper ontological structure of substance, form, or the classical distinction between act and potency. Instead, they introduce a modal language that distinguishes different levels of reality without returning to the first principles of being.

Summary of key points of modal interpretations:

- Quantum systems possess both actual and potential properties simultaneously.
- The wave function is used to determine which properties are actual.
- The interpretation employs modal language (possibility or reality) rather than classical metaphysics.
- Potentiality is acknowledged functionally but not grasped ontologically; the ontological structure remains incomplete and disconnected from the deeper metaphysical principles that govern being and change.

2.8 CSM interpretation

The CSM (Contexts, Systems, Modalities) interpretation, proposed by Alexandra Auffèves and Philippe Grangier, constructs an ontology based on the relationship between a system and the measurement context. Physical properties are not considered absolute, but rather as *modalities* tied to a specific experimental framework. In this sense, a modality refers to a property of the system that can be predicted with certainty and repeatedly confirmed within a given context.

This interpretation aims to bridge the gap between subjective and objective understandings of quantum reality. Although it acknowledges the role of measurement, a modality is not merely an expression of subjective belief but a stable feature of the relationship between a system and its context. However, the ontological framework of CSM remains contingently bound to measurement and does not emerge from general ontological principles. Instead, it focuses on an empirically grounded connection between context, system, and predictability without striving for a deeper metaphysical systematization.

Summary of key points of the CSM interpretation:

- The ontology is based on the relationship between the system and the context.
- Physical properties are understood as modalities rather than absolute entities.
- A modality is that which can be predicted and verified within a given framework.
- The model bridges subjectivism and objectivism, but its ontology remains contingently dependent on measurement.

3 Aristotelian Ontology and the Concept of Potentiality

Aristotle's ontology, as developed mainly in his *Metaphysics* [Aristotle, 1933] and *Physics* [Aristotle, 1957], is grounded in the fundamental distinction between two irreducible modes of being: *potentiality* (*dynamis*, *δύναμις*)[3] and *actuality*[4] (*energeia*, *ενέργεια*, or in its perfected form, *entelecheia*, *εύτελεχεια*). This distinction, far from being a merely linguistic or epistemological tool, reflects a real and ontologically robust duality within beings themselves: a *being* can be, and often is, not only what it *is*, but also what it *can be*[5].

[3]Throughout this text, if an entity—understood as an object of the microworld—is in a state of potentiality, it is referred to as BEING IN POTENCY.

[4]Throughout this text, if an entity—understood as an object of the microworld—is in a state of actuality, it is referred to as BEING IN ACT.

[5]Metaph. IX, 1, 1046a11–1046b30.

3.1 Potency and Act: Two Modes of Being

In Aristotle's thought, potentiality is not a deficiency but an irreducible mode of existence. BEING IN POTENCY means possessing an inherent capacity towards a certain realization. In contrast, reality is the full realization or fulfillment of that capacity. A lump of bronze is potentially a statue; the statue is the fulfillment of the bronze's potential to assume a specific form.[6]. The passage from potency to action is not the emergence of something from nothing but the fulfillment of an already present but unactualized capacity.

Importantly, Aristotle holds that potentiality and actuality are not merely epistemic categories - they are ontological states. The thing is not less real for BEING IN POTENCY. The potential of a child to become an adult is as real as the adulthood it will attain. What differs is not the degree of reality, but the mode of being [7].

3.2 Form, Matter, and the Structure of Change

This dualism of act and potency is closely related to Aristotle's broader metaphysical schema, particularly his hylomorphic theory, the doctrine that all physical beings are composed of *matter* (*hyle*, $\upsilon\lambda\eta$) and *form* (*morphe*, $\mu o \rho \varphi \eta$ or *eidos*, $\epsilon\iota\delta o \sigma$). Matter provides the substrate of potentiality, while form actualizes it in a specific direction[8].

Change, in Aristotle's system, is intelligible only by appeal to these principles: it is the actualization of a potential in a subject, under the determination of a form. This understanding of change is inherently teleological: Potency is always directed toward some definite mode of being, which constitutes its *telos* ($\tau\epsilon\lambda o \sigma$)[9].

3.3 Ontological Economy and Metaphysical Depth

One of the enduring strengths of Aristotelian ontology lies in its ontological economy: it does not multiply entities unnecessarily (as many-world interpretations do), nor does it reduce all being to what is presently observed (as epistemological

[6] Metaph. IX, 6, 1048a30–35.
[7] Metaph. IX, 3, 1047a24–30.
[8] Phys. I, 7, 190b10-191a22; Metaph. VII, 3, 1029a2-30.
[9] Phys. II, 3, 194b32-195a2; Metaph. IX, 8, 1050a4-20.

actualism does). Rather, it maintains that the world is richer than what is currently actual, that being itself includes the possible, the not-yet, the becoming[10].

This framework is not a naive metaphysics of the *possibility* as a mere human imagination or a logical abstraction. It is a robust account of the real capacities in things - capacities that structure the very dynamics of nature. This is particularly evident in the natural sciences, where systems exhibit lawful behaviors not only in what they are but also in what they are capable of becoming. The Schrödinger equation, for example, governs not just the evolution of states that are, but the possibilities latent[11] in the system's wave function.

3.4 Potentiality and the Challenge of Quantum Mechanics

Contemporary physics and quantum mechanics, in particular, have challenged the sufficiency of a purely actualist ontology. Quantum states seem to exist in superpositions and in configurations that defy localization, determinacy, or actuality in the classical sense. **Measurement - far from merely revealing what is - appears to actualize what was only potential until then.**.

In this context, Aristotle's metaphysical framework offers a way to restore intelligibility without sacrificing ontological rigor. It allows us to treat the wave function not as a mere instrument of prediction or as an ensemble of many worlds actualities, but as a real disposition toward being, structured potency awaiting actualization[12].

3.5 Example: A particle as a structured potentiality

Consider a particle described by a quantum state $\psi \in \mathcal{H}$, where $\mathcal{H}$ is a complex Hilbert space. Let us suppose that we are measuring an observable $\hat{A}$, for instance, such as the spin of the particle along a chosen axis. The operator $\hat{A}$ is Hermitian, which means that its eigenvalues, the possible outcomes of measurement, are guaranteed to be real numbers, corresponding to physically meaningful quantities. It possesses a discrete spectrum of eigenvalues $\{a_i\}$, each associated

[10] Metaph. IX, 7, 1049a5–25.

[11] More precisely, only those possibilities that can transition into BEING IN POTENCY are governed by the Schrödinger equation at a given moment, not all imaginatively conceivable possibilities. Moreover, the probability associated with each potential outcome is not arbitrary, but determined by the squared modulus of the wave function.

[12] Cf. Metaph. IX, 1–9.

with a corresponding eigenstate $|a_i\rangle$ that satisfies the eigenvalue equation:

$$\hat{A}|a_i\rangle = a_i|a_i\rangle.$$

The state ψ can be decomposed in terms of the eigenbasis of $\hat{A}$:

$$\psi = \sum_i c_i|a_i\rangle, \quad \text{where } c_i = \langle a_i|\psi\rangle.$$

This decomposition expresses the particle not as already in a specific state, but as possessing a structured set of possibilities[13], dispositions, to be realized in one of the forms $|a_i\rangle$ upon measurement. The squared modulus $|c_i|^2$ gives the probability that the measurement yields the value a_i and that the system is projected into the corresponding eigenstate $|a_i\rangle$.

Formally, measurement operates as a projection: the quantum state collapses onto one of the eigenstates of $\hat{A}$, realizing a specific outcome from among the structured potentialities encoded in ψ.

In Aristotelian terms, the state ψ represents BEING IN POTENCY — a real but unactualized mode of being. The eigenstates $|a_i\rangle$ constitute the formal horizon of possible actualizations; they are the FORMS toward which the potency of the particle is oriented. The coefficients $|c_i|^2$ represent the relative intensity or dispositional force of that orientation. Measurement serves as the ontological trigger that selects one of these structured potencies and brings it into BEING IN ACTUALITY.

Thus, the quantum description of the particle is not epistemic uncertainty but metaphysical structure: the particle is not indeterminate in the sense of lacking being, but is determinate in the sense of possessing ordered potentialities bounded by form. The Aristotelian framework allows us to say that the particle, prior to measurement, truly exists — not as actually being in a definite state, but as a unity of directed potentialities whose structure is fully encoded in ψ.

In this Aristotelian perspective, the wave function of the particle can be interpreted not merely as a mathematical object encoding probabilistic outcomes, but as a *form* (*morphe*) in the proper ontological sense. Structures the BEING IN POTEN-

[13] In a purely mathematical sense, the set of eigenstates $|a_i\rangle$ constitutes a complete orthonormal basis of the Hilbert space $\mathcal{H}$. However, in the ontological interpretation adopted here, this set is regarded as a structured unity: the potentials are not isolated but ordered according to the form that directs the system toward its realization. Thus, the term *structure* is used to capture not only the set-theoretical aspect, but also the internal ordering and orientation of potentialities toward actuality.

TIALITY of the particle by delimiting the set of possible actualizations under given experimental conditions. While the particle itself — considered as *hyle* (matter) — is not yet in any definite state, the wave function configures the full horizon of its potential modes of being. Thus, just as the classical form gives shape and direction to matter, the wave function gives ontological order to quantum potency. In the event of measurement, one of these structured possibilities is realized, and BEING IN POTENTIALITY transforms into BEING IN ACT. From this viewpoint, the wave function is not a representation of epistemic limitation or subjective belief, but an expression of the form *as possibility* — a dynamic ordering principle within quantum ontology.

This ontological correspondence between classical Aristotelian categories and their quantum mechanical counterparts is summarized in Table 1.

Table 1: Aristotelian Ontology and Its Interpretation in Quantum Mechanics

Aristotelian Concept	**Interpretation in the Quantum World**
Hyle (matter)	The particle itself as the bearer of possibilities.
Morphe (form)	The wave function that structures possibilities.
Dynamis (potentiality)	The real capacity to be in different concrete states.
Energeia (actuality)	The realization of one specific state upon measurement.

4 Conclusion

This article has argued that quantum mechanics, while mathematically rigorous and experimentally successful, remains ontologically unsettled. Its formalism describes phenomena that challenge the classical notions of determinacy, localization, and being itself. However, most contemporary interpretations either deny the reality of what is not actual or inflate the actuality to the point of absurdity. In doing so, they obscure the possibility of an ontologically balanced account of the quantum world. By reintroducing the Aristotelian distinction between potentiality and actuality as two coequal modes of being, this work has proposed a new interpretive framework: one that acknowledges the structured potency inherent in quantum systems and understands measurement not as an epistemic update, but as ontological realization.

What emerges is a vision of quantum reality in which potentialities are not mere fictions, but real dispositions, oriented toward actualization by the inner structure of form. The wave function is no longer a ghost in the machine, nor a subjective guess, but the formal horizon of becoming. This perspective does not simply reinterpret old puzzles; it changes the rules of the ontological game. Instead of asking which interpretation is *true*, we begin to ask: What kind of metaphysics must we adopt to make sense of quantum descriptions without ontological reductionism?

The answer, perhaps surprisingly, leads us back to Aristotle, not out of nostalgia but out of necessity. For it is his framework of structured potency and form-driven actualization that best accommodates the strangeness of the quantum world without dissolving its reality. In this light, quantum theory is not a paradox to be solved, but an invitation to recover what was never outdated: a metaphysics of being deep enough to hold both what is and what can be.

References

Petr Kulhanek. *Vybrane kapitoly z teoreticke fyziky*. AGA, 2024. ISBN 978-80-904582-8-4. URL https://www.aldebaran.cz/studium/tf.pdf. Available online.

Steven Weinberg. *Dreams of a Final Theory: The Scientist's Search for the Ultimate Laws of Nature*. Pantheon Books, 1992.

Roger Penrose. *The Road to Reality: A Complete Guide to the Laws of the Universe*. Jonathan Cape, 2004.

Carlo Rovelli. *Quantum Gravity*. Cambridge University Press, 2004. doi: 10.1017/CBO9780511755804.

Lee Smolin. *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next*. Houghton Mifflin Harcourt, 2006. ISBN 9780618551057.

Tim Maudlin. *Philosophy of Physics: Quantum Theory*. Princeton University Press, 2019. doi: 10.1515/9780691190679.

Aristotle. *Physics, Volume I: Books 1–4*, volume 228 of *Loeb Classical Library*. Harvard University Press, Cambridge, MA, 1957. URL https://www.loebclassics.com/view/LCL228/1957/volume.xml.

Aristotle. *Metaphysics, Volume I: Books 1–9*, volume 271 of *Loeb Classical Library*. Harvard University Press, Cambridge, MA, 1933. URL https://www.loebclassics.com/view/LCL271/1933/volume.xml.

Werner Heisenberg. *Physics and Philosophy: The Revolution in Modern Science*. Harper & Row, New York, 1958.

Bryce S. DeWitt and Neill Graham, editors. *The Many-Worlds Interpretation of Quantum Mechanics: A Fundamental Exposition*. Princeton University Press, 1973. ISBN 9780691618951.

Peter R. Holland. *The Quantum Theory of Motion: An Account of the de Broglie–Bohm Causal Interpretation of Quantum Mechanics*. Cambridge University Press, 1993.

Angelo Bassi, Kinjalk Lochan, Seema Satin, Tejinder P. Singh, and Hendrik Ulbricht. Models of wave-function collapse, underlying theories, and experimental tests. *Reviews of Modern Physics*, 85(2):471–527, 2013. doi: 10.1103/RevModPhys.85.471.

Hans Christian von Baeyer. *QBism: The Future of Quantum Physics*. Harvard University Press, 2016.

Robert B. Griffiths. *Consistent Quantum Theory*. Cambridge University Press, 2002.