**Book Review: The World in the Wave Function**

**- The Metaphysics of Quantum Physics by A. Ney**

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1. Preface: Philosophical Challenges of Quantum Physics

In the context of discussions surrounding quantum physics, there arises a proposition asserting that "we and the world are fundamentally one." This proposition bears resonance with various philosophical traditions such as Buddhist metaphysics, Daoist taiji(太極 yinyang), Confucian cheng(誠 integration), and Western idealism. However, quantum theory still appears distant and enigmatic to us. Today, we live in a reality where quantum physics excavates the realm of multiverse physics, and quantum engineering facilitates the emergence of an expanded reality akin to a metaverse[[1]](#footnote-1). Nonetheless, the language of quantum physics remains perplexing when it comes to explaining the world. Our human experiences and objects seem confined to three dimensions, yet certain interpretations of quantum physics portray 3D as 'abstract' and 11D as the 'fundamental' category. This disjunction between everyday experience and quantum language presents a significant gap. To bridge this gap, various philosophical inquiries into quantum physics are underway, and one such contender is Alyssa Ney's book, "The World in the Wave Function: A Metaphysics of Quantum Physics."[[2]](#footnote-2) Ney, the author of the book, adopts the question, "How does the macroscopic world emerge from the microscopic world?" as the most profound challenge of quantum physics in her endeavor to address this gap. She articulates a thesis that "both we and the objects in the world are composed of wave functions" (pp. ix-x), building upon the wave function realism of D. Z. Albert and Barry Loewer.

The esoteric nature of quantum physics is well illustrated by an experiment involving a double slit apparatus[[3]](#footnote-3). In this experiment, consisting of a device with a slit labeled ⓗ in the first screen, slits labeled ⓘ and ⓙ in the second screen, and a third screen ⓚ, when a particle x is sent through the first screen ⓗ, x reaches the third screen ⓚ, but it is not known which slit it passed through, ⓘ or ⓙ in the second screen. This is not due to a lack of technology or cognitive limitations, but to the nature of quantum physics itself, which is why it seems like a paradox in everyday language. This is because 'understanding' and 'explanation' in everyday language is composed of the basic concepts of the Cartesian/Newtonian/Kantian paradigm, such as individuality, identity, and causality. The quantum paradox arises when we try to understand the words 'observation' and 'measurement' in terms of the old paradigm. The author characterizes the measurement paradox as an incoherent triad (p. 15).

1. Quantum physics causes the amplitude of a particle's wave function to move with all possible values at every point.
2. Given (1), quantum physics ensures that states keep to evolve continuously into the future.
3. Measurements always yield results that are local or definite concerning the values of variables.

The paradox arises from this discrepancy because quantum states are nonlocal, but the values on which measurements depend are local.

This paradox is taken to stem from the quantum nature of subatomic particles, such as the superposition of light as both particles and waves or of Schrödinger's live and dead cats. Furthermore, the entanglement state Ψab, in which the states of particles a and b, no matter how far apart they are, are so connected that, due to past interactions, they appear as superpositions when measured, is also described as "the most characteristic aspect" (p. 50) of quantum theory. It is natural to ask the following questions about such elementary particles: Just as atoms have extension, do elementary particles have extension? The notion of extension is open to many interpretations, but even if it is understood as Cartesian extension, how would the ontology of quantum phenomena be defined if quanta did not have extension, but instead appeared as a plot of amplitudes represented by wave functions? The author of the book focus on these questions. This article will first summarize the book (sections 2-3) and then discuss the book (sections 4-6).

**2. Reality of Wave Functions: Separability and Localizability of Configuration Spaces**

Are wave functions, which do not have the extension unlike atoms, real or unreal? The author believes that "it is impossible to give an objective description of the full range of quantum states, including entanglement states, unless we acknowledge the reality of wave functions and take them to be physical fields in higher-dimensional space" (p. 49). Furthermore, in order to give an objective description of entanglement states, we must "regard wave functions as real physical fields in higher-dimensional space that constitute the material of our universe" (p. 52). The author then considers several competing ontologies of wave functions: the primordial ontology holds that everyday space-time is essentially composed of local beables (pp. 56-62); the holism theory holds that the wave function does not exist in and of itself, but is a property of the holistic entangled system that is the universe (pp. 63-67); the relational theory holds that quantum systems are entangled not as individuals but as pairs of structural relations between phenomena represented by equations (pp. 67-71).

The author's ontology of the wave function is based on a configuration space that preserves separability and locality (pp. 149-165). According to the author, while single-particle systems are understood as wave functions assigned to points in everyday space, three-dimensional space, many-particle systems are interpreted as wave functions assigned to points in a different kind of space, configuration space. "Each point in the configuration space corresponds to a list of deterministic positions of each particle of the system" (p. 37). Thus, a single point can be used to represent all the particles of a system, and a single curve can be used to represent the temporal trajectories of all the particles.

If we can accept the authors' conception of configuration space, then the configuration space becomes central and fundamental to the ontology of the wavefunction. This is because it does not have to require the wavefunction to be a physical field, nor does it require the entanglement state to be high-dimensional. Properties, relations, and laws can be interpreted ontologically on the basis of configuration space rather than everyday space (pp. 76-78), and the property of separability can be read from the determinate positions of particles in the configuration space. Separability is a fundamental ontological principle that regulates the individuation of states associated with physical systems, a principle implicit in classical mechanics. If entanglement forces us to ignore the separability condition, it is because we view inseparability as a ubiquitous property of quantum physics. However, the author proposes a way to respect entanglement and still preserve separability: all states of the wavefunction, including entangled states, are fully determined "through local assignments where the amplitude and phase of the wavefunction are separable at every point in the wavefunction's high-dimensional space".

The author also suggests that the property of locality can be interpreted within the framework of the configurational space. While many quantum physicists have embraced the idea of non-locality in the context of Bell's theorem, the author advocates for a form of realism that requires locality. Realism demands that measurements must be possible and that "this measurement must be local" is deduced from the concept of measurement. If non-locality or inseparability is consistently adopted, one must deny the numerical distinctness of individuals within entangled states. If two systems are not separable, they cannot interact because they are not independent systems. The numerical distinctness of individuals is necessary for measurements that rely on such distinctness (pp. 113-114). Additionally, the notion of "intrinsic relations," not determined by the intrinsic natures of the relata, allows for a relational holism that can avoid non-locality. In a Bohmian device, stable correlations between two atoms exist, but due to the intrinsic relations connecting them, there is no reason to infer a causal structure from these correlations (p. 115). But isn't there still a tension between the basic non-locality of the world and the locality of realism?

To address this tension, the author introduces a more "weaker" concept of locality, relying on a Humean supervenience metaphysics (pp. 127-129):

(4) Everything in the world is a mosaic of local material particulars of determinate facts.

(5) We have a geometry of the systematic extrinsic relations of spatiotemporal distances between points.

(6) There exist intrinsic local properties of natural kinds, no larger than points.

(7) There is no difference that does not make a difference among the properties' arrays.

(8) Everything else follows from these.

Based on this supervenience theory, the author believes that it is simpler to have a set of fundamental entities in our space upon which everything depends, and that no additional relations are needed to explain quantum entanglement. And the author states:

 (9) There are non-separable facts and non-local operations;

 (10) Separability and locality have distinct meanings.

Although these two propositions appear to be contradictory, he sees no need to deny proposition (10) while accepting proposition (9) (p. 131). The question is whether to blindly accept these two propositions as facts of our world, or to attempt to explain them by exploring the underlying deeper metaphysics.

**3. Abstraction of macroscopic objects from microscopic realities**

Author Ney presents a rebuttal to a critique of wave function realism regarding the absence of a fundamental entity in quantum ontology, as put forth by proponents of wave function primitivists including T. Maudlin. The critique (p. 167) argues that

(11) An ontology for quantum physics must be able to organize macroscopic objects, including us and the objects around us;

(12) In order to do so, an ontology for quantum physics must recognize a class of primordial localizers, beables as entities endowed with specific locations in three-dimensional spacetime;

 (13) Wave function realism does not include such fundamental local beables;

(14) Therefore, wave function realism is misleading as a framework for interpreting quantum physics.

In response to this criticism, the author rejects the claim that "the basic ontology of quantum physics consists of low-dimensional objects spread out in three-dimensional spacetime" and argues that it should not include localized beables. While agreeing with the primitivists that "the quantum world is a world of low-dimensional macroscopic objects, including those that interact with us," he asks "what are the primordial entities that constitute these objects in the quantum world" (p. 169).

Before answering this criticism directly, the author introduces one way of responding to the constructivist objection. Primitivism's proposition (11) is not reductionist, but it does imply a unified scientific theory: "The entities of physics form the basis of the constitution of all other entities”. Unificationism wants the laws to apply foundationally in all cases, but reality may be an aggregation of laws (p. 171n). Thus, the author contends that while not rejecting the claim that "quantum ontology constitutes macroscopic entities, including us," one can reject the assertion that "quantum ontology must include a fundamental local beable ontology" (p. 172).

If beable ontology were true, then the overlap principle would be justified when it says that quantum theory is predicated by local beables and evidence consists of such beables. However, according to the author, the overlap principle is empirically inconsistent (p. 174) since beables are unobservable by definition. Consequently, if there is no overlap between evidence and ontology; if evidence escapes or transcends ontology, then the problem arises that evidence does not exist. Beable ontology becomes a hard position to justify.

What, then, in the quantum world constitutes macroscopic objects in lower dimensions, such as the third dimension? The author takes six steps toward answering this question.

The first step is a mapping between macroscopic entities and wavefunction structures (pp. 199-207). The question is: How can apparently spatially separated objects be constructed from a single object, the quantum wavefunction? A simple correlation can be assumed between the states of the wavefunction and the system of particles or atoms in three dimensions. This is because the wavefunction can be defined in a space where each point corresponds to a specific arrangement of particles. We can then observe where the wavefunction is in higher-dimensional space with non-zero amplitude, infer the existence of a corresponding three-dimensional array of particles, and infer the existence of a macro being that has collected the particles in this array. Of course, the author acknowledges that the mapping between macroscopic existence and wavefunction structure is necessary but not sufficient to base the existence of macroscopic objects on the universal wavefunction.

The second step in constructing lower-dimensional macroscopic entities is to reduce the three-dimensional macroscopic entities to wave functions through functional reduction. Quoting Jaegwon Kim (p. 211), the author expected functional reduction to be "the functional role of the entity being reduced" and "specifying the entities of a more basic ontology that can play that functional role". If this goal is achieved, then the hypothesis that "three-dimensional objects are constituted by more basic ontological beings" will be

 justified. However, the author believes that this functionalism presupposes an absolutist frame of space, in the sense that it conceives of objects as having a fixed and constant position. The author calls for functionalism to be approached from a relational structuralist frame (p. 212), in line with D. Z. Albert. She asks questions such as, "What relations must be present in order to obtain a set of beings that can be properly described in three dimensions?" and "Do the parts of the wave function realize these relations?" These questions lead to questions such as "how do we extract three-dimensional micro-entities from a wave function in a higher-dimensional space?" and "how do we extract three-dimensional macro-entities from three-dimensional micro-entities?", thus directing the task toward macro-entities.

The third step is to simulate the symmetry between the wave function and the lower dimensional object. The author is favorable to the view that "there is no a priori conceptual obstacle to the idea that three-dimensional macroscopic objects arise from elements of the wave function ontology. This is because the "preferential but natural dynamical process of decoherence" allows for localized systems that "persist in wave function space" (p. 220). These are systems that behave "as if they existed in a fixed three-dimensional world, thanks to the symmetry of the three-dimensional systems." Thus, we can consider that classical objects emerge from their quantum states thanks to the existence of a pattern of quantum states. Three-dimensional objects are patterns of those quantum states (p. 221). In this sense, we can say that the parts of the wave function observe symmetry with the three-dimensional object. It is possible for a wave function to simulate a lower-dimensional object. However, what is needed is more than these simulated dimensions, for which we must rely on functionalism, so the author move on to the next step.

The fourth step is the recoverability of three dimensions. For the author, the recovery of the third dimension is obtained from the direct relationship between the "state of the wave function as a whole" and the "three-dimensional micro arrangement as a total" (p. 226). The concept of the "metaphysical grounding" is central to the discussion of the arrangement of macroscopic objects. This is because there is a descriptive gap between the micro and the macro. For example, there is no transparent causality in the relationship between H, H, O, and H2O molecule, but the molecule is connected by metaphysical grounding principles. The metaphysical explanation of these connections is mediated by a mereology of parts that relates them to a holistic being and nature (p. 229). The way to discover the three-dimensional objects in the wave function, then, is to "observe its dynamic behavior rather than focusing on the state of the wave function at any single time" (p. 232). This strategy starts from the fact of permutation invariance between quantum states (states of the wave function) and uses the principle that "permutation invariants show the existence of symmetries" (p. 232). The connection between dynamical permutation invariants and symmetry is that the wave function can be seen as constituting a particular three-dimensional ontology. It is then possible to draw a corresponding picture for three-dimensional particle arrays. We have the basis for three-dimensional recoverability.

The fifth step is the recovery of the third dimension. To bridge the explanatory gap between wave functions and macroscopic objects, the author specifies the metaphysical relationship between them. We start with the proposition that "the wave function is the fundamental whole, and the particles are its derivative parts" (p. 240). Since only the wave function is real and fundamental, it follows that for lower-dimensional particles to be real, they must be constructed from the wave function. The spatial arrangement of particles is also considered a property attributable to them. Plural arrangements of particles, when realized by a wave function, are each realized to a degree equal to the amplitude of the wave function at its squared point. Rather than a complete realization of classical logic (an entity e is either F or non-F), she opts for a partial realization of virtue logic (wisdom, justice, piety, honor, etc. come in degrees). Three-dimensional particles can then occupy various positions in varying degrees while relating to the whole, which is the wave function, in a mereology of parts (pp. 242-243).

The final step in the construction of lower-dimensional macroscopic objects is to locate the world within the wave function. If particles occupy various positions in varying degrees, then macroscopic objects are abstractions from a larger reality (p. 247). This is because the world as it appears in three- or four-dimensional space is actually a field in higher-dimensional space. It is then possible to say that "all objects are in some sense phases of the one" (p. 247). This is in line with certain abstract ontologies in the East and West. The author can say that "we are fundamentally parts of the one" but distances himself from the proposition that "we are completely the one".

In conclusion, the author sees no conceptual impediment to understanding the relation between the wave function and the micro particles as a relation of parts and wholes when we locate the world in the wave function, and affirm that "the micro particles do not have a definite position, but embody that position in partial degrees" (p. 249). If we allow that micro particles embody determinate positions, then we can use ordinary functionalist strategies to recover everyday macroscopic objects

**4. The abstractness of measurement**

As can be seen from the summary above of the book's contents, this book represents an important step in the history of philosophy. Just as Newtonian mechanics was published in 1728 and Kant philosophized it about 50 years later in 1781, so the proposal of quantum physics in the 1920s and the concrete presentation of the author's "Metaphysics of Quantum Physics" in 2021, nearly 100 years later, is a noteworthy event, along with the contributions of several quantum philosophers since Whitehead's "Process and Reality" in 1929. The reviewer would like to reflect on the author's important and challenging work. First, the author's insight that the macroscopic picture is abstract (p. 247) is brilliant. This is because the macroscope is a "construction" from a more basic and larger reality, the wave function. But what about the act of measuring itself? As shown in Section 1, the author expresses the measurement paradox in three incoherent propositions, but is the paradox due to the abstractness of measurement? And what is the relationship between "construction" and "measurement"? Perhaps the author is not presenting enough discussion of the concept of measurement itself, or perhaps she is saving it for another time.

The act of measurement is abstract. This is not only because measurement is an abstract process, but also because any measurement has an element of underdetermination. Humans observe with a pair of glasses that fit them. The more detailed the observation, the more we can affirm that no observation is made without tools. This situation allows for the proposition that there is no "presuppositionless observation". There is no frameless observation. So, can we say that the kind of observation that has historically been practiced by the mainstream of human intellect is Cartesian-Newtonian observation? Concepts such as individuality, identity, and causality are all processed by our everyday senses, but are they not based on the conviction that our everyday senses have the ability to transparently reflect reality? Without that conviction, we would not be able to arrive at the conceptual structures such as understanding and explanation that human society currently uses. As Descartes believed, the human senses are mirror-reflections of reality. In other words, human observation has largely been taken to be a representation of the reality, allowed by the human senses but guaranteed by undeceiving God.

Quantum physics is shaking up the idea of Cartesian-Newtonian observation. Descartes arrived at the "indubitable" certainty of my existence through the proposition "I think, therefore I am." This certainty was understood as the inevitability structure of the traditional notion of modality, based on concepts such as individuality, identity, necessity and causality. However, the metaphysics of quantum physics can be interpreted as not allowing the referentiality of individual names.[[4]](#footnote-4) The traditional notions of those concepts are something that must be reconsidered according to quantum physics. A reader is naturally bound to be eager to listen to the new construction of those concepts as fundamental to philosophical thought in the space of pursuing the metaphysics of quantum physics. If the concept of measurement already lays the foundation for the concept of "quantum observation," such a task seems even more imperative.

**5. Reality Criteria**

The author has argued for the existence of wave function realism, but has not discussed the criteria for realism in detail. Throughout the history of philosophy in the East and West, the concept of reality has been proposed by almost every philosopher in one way or other. The author's realism should not be taken to be one among many versions of realism , most of which have been under the influence of Cartesian paradigm, having joined the new paradigm of quantum physics. Then at the very least, one may be interested in seeing more clearly the differences between the two paradigms. One might assume that the difference is self-evident, but the difference will only become clearer through propositions. In response to this question, the reviewer would like to explore the possibility of the following proposition: "If Cartesian/Newtonian reality is the reality of eternal necessity, then Einsteinian/Quantum reality is the reality of relative contingency". I wonder if Hawking had this distinction in mind when he said that "philosophy is dead"?[[5]](#footnote-5)

The difference between classical and contemporary notions of reality can be discussed more specifically. Classical or Newtonian reality as eternal inevitability has been constructed under a particular notion of individuality, of identity. An individual is a real entity whose absolute organization is assumed to be invariant over time. For two arbitrary individuals, a and b, identity is necessary, as in "If a is b, then a is necessarily b." However, contemporary realism as relative contingency means that entities can vary as individual entities and that necessities depend on semantic systems. The temporal and spatial dimensions of matter are relative, and even the locality at every point in the wave function of subatomic particles making up the universe is contingent. While classical realism excludes the observer, human, or consciousness, contemporary realism suggests the possibility of involvement by an observer, "I," or consciousness due to the existence of objects in everyday life or macroscopic objects appearing abstract and mysterious in the face of the profound reality of the microcosmic world. This leads us to acknowledge our ignorance, realizing that we know less than we think. Therefore, the request for criteria for her realism becomes even more pronounced. What are the contemporary conception of key concepts alternative to the classical conception?

This question may be unfair to the author. She may not be aiming for a mere hypothesis of the reality of wave function, but a concept of reality that predicates "<the configuration space in which the wave function is represented is a fundamental physical space>.” She is striving for ontological fundamentality rather than criteria for reality. By doing so, she hopes to secure separability and locality. Of course, one might ask whether separability and locality can be requested as criteria for ontological fundamentality. The author's strategy of one platform for different interpretations of quantum physics while we in the contemporary world still cannot give up the apparatus of individuality, identity, etc. is understandable. However, it is hoped that the connection between her proposition (9) and proposition (10), which differentiates the classical criterion of existence from alternative wave function ontologies, can be given greater weight.

**6. The Mystery of Consciousness**

The author, without delving deeply into the subject of consciousness, asserts a divergence from many scholars who bridge the gap between physical reality and consciousness, suggesting that this gap can be reconciled (pp. 230-231). This stance seems to align with the prospects offered by the advancements in cognitive science and neuroscience. Could the influence of Jaekwon Kim’s "sufficient physicalism" be a factor in this perspective? However, it's worth considering that Kim's later theory maintained a distance from the objective ordering of subjectivity in first-person consciousness[[6]](#footnote-6).

The author's rejection of the gap in the mind-body relationship should be presented in a more concrete manner. For instance, it should address David Chalmers' "hard problem of consciousness," which posits that conscious experience cannot be explained by reducible cognitive functions. Additionally, one might inquire about the author's stance on Roger Penrose's "consciousness fundamentality," which argues that consciousness is non-computational.

When the author thinks that "macroscopic objects are abstractions" (p. 247), is the abstractness of macroscopic objects independent of consciousness in any sense? If we accept the "it from bit" hypothesis, where does the bit information come from? Information is a holistic thing. If we accept the hypothesis that "truth is verified not by individual sentences but by the totality of the theories in which they are embedded," then yes, consciousness is also holistic. There are localized consciousnesses like pain and itching, but consciousnesses like belief and hope are holistic. So what is the relationship between information and consciousness? Is information an abstraction of consciousness? One clue may come from the collectivity of quantum states. A quantum elementary particle is referentially[[7]](#footnote-7) not a nominally singular entity, but a superposition of wave functions of the particle, which can be described as wave functional fullness in the sense that it has every point in the universe as a value of its wave amplitude. What does the wave functional fullness of elementary particles indicate about the totality of information and the totality of consciousness? I look forward to further exploration.

The author presents the "world as a wave function" proposition as the thesis of the book. The author's argument has considerable appeal. However, it does not address the question "Is consciousness a wave function?" Does the book's thesis imply the proposition "consciousness as a wave function"? Why didn't the author explore the possibility of such an implication more actively? If the author wanted to bridge the gap between the microscopic and macroscopic objects of wave functions, they should also be able to bridge the gap between the microscopic objects of wave functions and the phenomenon of consciousness. Furthermore, shouldn't we be able to bridge the gap between the microscopic phenomena of wave functions and the phenomena of para-psychology at some point? Evidence for hypnotism, mind reading, precognition, clairvoyance, clairaudience, spiritualist rituals, shamanism, divination, mediumship, telekinesis, etc. is negligible, but their reports abound.

In conclusion, the wave function realism of this book that the world is composed of wave functions can be summarized in the following six propositions: There is a correlation between the states of wave functions and the three-dimensional particle system; three-dimensional macroscopic objects can be reduced to wave functions by functional reduction; wave functions and three-dimensional objects can be simulated by symmetry; the recovery of the third dimension consists of a direct relationship between the states of wave functions as a whole and the three-dimensional micro arrangements as a total; three-dimensional particles are mereologically related to the wave function whole, and these particles do not normally occupy definite positions, but may occupy various positions to varying degrees; if they occupy various positions to varying degrees, then macroscopic objects are abstractions from a larger reality. This wave functional realism could be strengthened by complementing topics such as the abstractness of measurement, criteria of reality, and wave functional consciousness. This book will be of interest to the philosophical community because it represents a metaphysics of quantum physics with the proposition that "all objects are in some sense phases of the One"[[8]](#footnote-8).

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1. Chung (2022c). [↑](#footnote-ref-1)
2. Ney (2021). [↑](#footnote-ref-2)
3. Zhang (2019: pp. 239-242); Chung (2022a: p. 334). [↑](#footnote-ref-3)
4. Chung (2022b), pp. 115-128. [↑](#footnote-ref-4)
5. Hawking, S. & Mlodinow, L.(2010). It is paradoxical that Hawking was actually doing philosop[hy in this book or in any other book. [↑](#footnote-ref-5)
6. Kim (2000: pp. 141-142). [↑](#footnote-ref-6)
7. Chung (2022b: 120). [↑](#footnote-ref-7)
8. This review could have been greatly improved through the sharp evaluation of anonymous reviewers. Thanks for the helpful assessment. [↑](#footnote-ref-8)