

Intersubjectivity and Reciprocal Causality within Contemporary Understanding of the God-World Relationship

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Quantum Mechanics and an Ontology of Intersubjectivity: Perils and Promises

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Abstract: Contemporary theology has realized the importance of integrating what we know from the “new physics”—quantum mechanics and relativity theory—into the metaphysical and ontological categories used by theology to consider God, the world, and the God-world relationship. The categories of subjectivity and relationality have risen to prominence in these discussions. Both academic and popular presentations can obscure the vital distinction between what physicists agree on concerning quantum mechanics and the contested interpretation of quantum mechanics, or what quantum mechanics reveals about reality. After (1) summarizing the significant distinction between quantum mechanics per se and the interpretations of quantum mechanics and (2) the agreed upon quantum mechanical experimental procedure and its attendant mathematical formalism, as well as a few of the foremost interpretations, this paper (3) attempts a minimalist culling of some rudimentary but clear ontological principles and categories from what is agreed upon in quantum mechanics, without appeals—tacit or explicit—to one of the many controversial interpretations or to contestable philosophical assumptions and deductions, and these are: experience, subjectivity, relationship, and event. The paper closes by (4) commending one speculative scheme that is especially conducive to developing an interpretation of quantum mechanics consonant with the ontological principles and categories so derived, that of Alfred North Whitehead.

Keywords: Metaphysics; Science; Philosophy; Physics; Quantum Theory; Theology; Process Thought; Process Theology; Alfred North Whitehead; Interpretations of Quantum Mechanics

1 Introduction

Christian theological discussions of the God–world relationship have always employed the metaphysical categories of a particular era. These, in turn, have been bound up with the dominant physical theory. Accordingly, today there are efforts to construct ontologies prioritizing intersubjectivity upon the basis of quantum mechanics. This entails both perils and promises.

One peril is the hiatus between *interpretations of quantum mechanics* and *quantum mechanics per se*. Whereas the latter is well-established and agreed upon, practically everything about the former is contested. This essay’s thesis is that although their disputed nature makes drawing upon interpretations of quantum mechanics for ontology untenable, a minimalist analysis restricting itself to areas of consensus still reveals interrelational intersubjectivity to be in some sense ontologically basic.

The first section summarizes agreed upon quantum mechanical experimental procedure. Next comes a survey of dissimilar interpretations of quantum mechanics and why they are questionable foundations for ontology. The next section makes a case for how quantum mechanics per se points to interrelational intersubjectivity as a fundamental ontological fact. The essay closes with a brief proposal for a way forward with one speculative philosophical schema congenial to quantum mechanics, that of Alfred North Whitehead.

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2 Consensus: Quantum mechanical experiments

To see how a minimalist analysis of quantum mechanics apart from broaching its diverse interpretations still reveals intersubjectivity as ontologically basic we must first differentiate the former from the latter. Quantum mechanics involves mathematical models for predicting the probable results of experiments prepared and measured according to certain procedures. Essentially, quantum mechanics is a scientific method—and an extraordinarily successful one—for predicting the probabilities of obtaining specific measurement outcomes given an experimental scenario. The theory is limited to the mathematical formalism used to make these predictions.

A basic fact differentiating quantum mechanical from classical state¹ descriptions of physical systems is *uncertainty relations*. Uncertainty relations are why a quantum state's future is predictable only with probability and statistically, not with certainty and precisely. These are relationships between certain pairs of values characterizing a quantum system which cannot be measured at the same time with definiteness (“incompatible observables”). The precision with which one can be measured stands in inverse proportion to the precision with which the other can be measured. These values are “complementary” because together they encompass all possible information about the event. Originally liable to being interpreted as an epistemological limitation,² the uncertainty principle is arguably an essential quality of wave-like systems,³ which include all matter.⁴ Uncertainty relations mean the choice of experiment determines whether and how accurately a “property” (or “quantum number”) will be measured.

The experimental method itself is relatively simple. First, a system to be measured or the “observed system” is set up in one location and a measuring apparatus or the “observing system” is set up in another. Next, what is initially known about both systems is translated into the mathematical formalism. The observed system is treated quantum mechanically and the observing system is treated as a classical physical object.⁵

1 A physical system's “state” is its mathematical description containing values like position and momentum.

2 The most well-known uncertainty relation is the Heisenberg uncertainty principle (or “indeterminacy principle”), which regards the inverse relationship between precision in measuring “position” and “momentum” (Heisenberg, “*über den anschaulichen Inhalt*”, 172–198). Heisenberg initially used the “observer effect” as an explanation: the measurement interaction affects what is being measured (Heisenberg, “*über den anschaulichen Inhalt*”, 174–175). This lent itself to an epistemological construal. Bohr realized this assumes particles are classical objects with definite properties that change by interacting with other objects. Jettisoning these classical assumptions, Bohr concluded the uncertainty principle involves two seemingly contradictory manifestations of physical reality appearing under different experimental arrangements, only one of which allows using the concept of “position” unambiguously and only one of which allows using the concept of “momentum” unambiguously (Bohr, “Causality and Complementarity”, 292–293). Together these distinct concepts provide a complete picture of the event.

3 Rozema, et al., “Violation of Heisenberg's Measurement-Disturbance Relationship by Weak Measurements”, 1–5.

4 In his 1924 doctoral dissertation, Louis de Broglie argued that not only light but also matter exhibits both wave-like and particle-like behavior. The results of two independent experiments published in 1927 and 1928 confirmed de Broglie's hypothesis. These experiments measured diffraction—a property of waves—for electrons. This meant that wave equations could be used to describe matter. Since then, de Broglie's “matter wave” theory has been proven correct for other subatomic particles as well as atoms and even larger configurations of matter.

5 Treating the observing system classically is pragmatically necessary because of uncertainty relations and for the scientific community to be able to discuss and tests the results: “It is impossible . . . to formulate the basic concepts of quantum mechanics without using classical mechanics. The fact that an electron has no definite path means that it has also, in itself, no other dynamical characteristics. Hence it is clear that, for a system composed only of quantum objects, it would be entirely impossible to construct any logically independent mechanics. The possibility of a quantitative description of the motion of an electron requires the presence also of physical objects which obey classical mechanics to a sufficient degree of accuracy. . . . In this connection, the ‘classical object’ is usually called the *apparatus*, and its interaction with the electron is spoken of as *measurement*. . . . By *measurement* in quantum mechanics, we understand any process of interaction between classical and quantum objects . . . Thus quantum mechanics occupies a very unusual place among physical theories: it contains classical mechanics as a limiting case, yet at the same time it requires this limiting case for its own formulation” (Landau and Lifshitz, *Quantum Mechanics*, 2–3) (emphasis theirs); and “[I]t is decisive to recognize that, *however far the phenomena transcend the scope of classical physical explanation, the account of all evidence must be expressed in classical terms*. The argument is simply that by the word ‘experiment’ we refer to a situation where we can tell others what we have done and what we have learned and that, therefore, the account of the experimental arrangement and the results of the observations must be expressed in unambiguous language with suitable application of the terminology of classical physics” (Bohr, *Foundations*, 209) (emphasis Bohr's).

The mathematical formalism depicts correlations between the observed and observing systems. The Schrödinger wave equation describes the deterministic evolution of the observed system as it is experimentally isolated and the corresponding possibilities for measurement outcomes before any measurement takes place. From the wave equation probabilities are calculated in a probability density function, which indicates the probabilities of the various possible measurement outcomes or “observables” at any time.⁶

The wave function contains superpositions of mutually exclusive possibilities until “measurement.” Measurement occurs when the measuring apparatus interacts with the observed system and does not imply a human observer.⁷ At measurement the probability of one possible outcome becomes one (definite) and the probabilities of all others become zero (definitely not).

Quantum mechanics, then, involves predicting and taking measurements of sub-microscopic phenomena by macro-scale measuring apparatuses prepared according to certain experimental procedures, using a mathematical formalism that has proven itself reliable in doing so time and again. What this means for understanding reality, however, is highly contested.

3 Dissension: The interpretation of quantum mechanics

This essay’s thesis states that debate over the interpretation of quantum mechanics makes any interpretation unstable footing for an ontology of intersubjectivity. Why? Interpretations of quantum mechanics propose what quantum mechanics tells us about the world but entail a host of controvertible answers to foundational questions, many of which are philosophical.

What are these foundational questions? General epistemological and ontological issues—such as realism vs. anti-realism—are bound up with more specific questions including:

1. What is the ontological status of the wave function? What does it represent? Does it correspond to something in the world? If so, then what and how?
2. How are the many probabilities reduced to one certainty in a measurement interaction (“collapse of the wave function”)?
3. Is the wave function’s collapse ontologically significant? Does it really collapse? What causes its collapse? (“measurement problem”)
4. What is the status of the possibilities before and in relationship to measurement?
5. What are the statuses and roles of the measuring apparatus and observer(s)? (Do they cause wave function collapse? Do they together constitute a single quantum system?)
6. Are there well-defined properties prior to and independently of measurement?
7. Is there a universal wave function for all of reality?
8. Is quantum indeterminism ontological or epistemic? Is there a hidden determinism?
9. What do the experimental violation of Bell’s Inequalities mean?
10. Do measurements not made have definite values (“counter-factual definiteness”)?
11. Can and should the mathematical formalism be modified?
12. Are quantum state descriptions “complete”?⁸
13. Is quantum theory “maximal”?⁹

⁶ There are two other mathematical formulations, Heisenberg-Born-Jordan’s matrix mechanics and Dirac’s nonrelativistic formulation. All three are equally reliable methods for calculating probable measurement outcomes.

⁷ “[W]e are here not discussing a process of measurement in which the physicist-observer takes part. By measurement, in quantum mechanics, we understand any process of interaction between classical and quantum objects, occurring apart from and independently of any observer” (Landau and Lifshitz, *Quantum Mechanics*, 2–3).

⁸ Some allege quantum theory is incomplete because the mathematical state representation does not contain an element for everything in the physical system. Others argue it is complete because the formalism contains predictions for every possible experimental arrangement and outcome.

⁹ Some contend quantum theory is not maximal because it predicts only probabilities, not certainties. Others argue it is maximal because it can be expressed entirely in true or false propositions, just like classical mechanics.

Disparate interpretations supply different answers to these and other foundational questions. Some answers are more consistent with others, so they come in ensembles.¹⁰ Several polls—in 1997,¹¹ 2011,¹² and 2013¹³—highlight the disagreements among physicists on how to answer these foundational questions. Despite expressing their limitations and qualifying their conclusions,¹⁴ the poll reports reveal that there is no consensus on the interpretation of quantum mechanics.¹⁵ Interestingly, in both 2011 and 2013 about 40% admitted they had switched to a different interpretation one or more times, while 58% in 2011 and 40% in 2013 agreed that “a lot” of one’s choice of interpretation is “a matter of personal philosophical prejudice.”¹⁶

The following surveys how some major interpretations address these questions differently. The purpose is not to advocate for specific answers or a particular interpretation but to see how there is nothing approaching an accord.¹⁷ This disagreement significantly weakens arguments for an ontology of intersubjectivity resting on any one particular interpretation.

The “Copenhagen Interpretation” has long been popular with physicists and is frequently presented as the mainstream interpretation. In 1997, 27.1%, 42% in 2011, and 4% in 2013 selected it as their favorite interpretation.¹⁸ Commonly associated with Bohr and Heisenberg, the name “Copenhagen Interpretation” was coined by Heisenberg in the 1950s and arguably now denotes more his own interpretation, which differs from Bohr’s.¹⁹ Although neither would say the wave function corresponds to something objectively real,²⁰ Bohr espoused metaphysical realism more explicitly.²¹ Both saw state reduction as indeterministic but the observer causing the wave function’s collapse defines Heisenberg’s interpretation, not Bohr’s. This role of the observer is immediately relevant to the question of ontological intersubjectivity. Coupled with the assumption that the wave function’s collapse corresponds to a change in objective physical reality,²² it is regularly used as “evidence” that subjectivity is a necessary condition for being.

10 For example, in the mathematical formalism the wave function’s collapse is ineluctably indeterministic. Therefore, interpretations with an actual wave function collapse are indeterministic while interpretations with no real collapse are usually deterministic.

11 Tegmark, “The Interpretation of Quantum Mechanics”, 855. Tegmark polled 48 attendees of a quantum mechanics conference at the University of Maryland, Baltimore County.

12 Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 222–230. Of the 33 respondents at this 2011 “Quantum Physics and the Nature of Reality” conference held in Traunkirchen, Austria, 27 identified physics, 5 philosophy, and 3 mathematics as their main academic affiliation (multiple answers were allowed).

13 Norsen and Nelson, “Yet Another Snapshot”, 1–11. This polled attendees of the 2013 “Quantum Theory Without Observers III” conference held in Bielefeld, Germany. There 76 respondents answered the same questions that were in the 2011 poll.

14 Tegmark, “The Interpretation of Quantum Mechanics”, 855; Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 222–223, 226; Norsen and Nelson, “Yet Another Snapshot”, 1, 8–10. Noted limitations include sampling bias.

15 “[T]he foundations of quantum mechanics themselves remain hotly debated in the scientific community, and no consensus on essential questions has been reached. . . . Today, debates about the foundations of quantum mechanics show no sign of abating . . . Quantum theory is based on a clear mathematical apparatus, has enormous significance for the natural sciences, enjoys phenomenal predictive success, and plays a critical role in modern technological developments. Yet, nearly 90 years after the theory’s development, there is still no consensus in the scientific community regarding the interpretation of the theory’s foundational building blocks” (Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 222, 227, 229).

16 Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 226; Norsen and Nelson, 6–7.

17 To take but one example, the summary of a position that claims indeterminacy is merely apparent because “hidden variables” mask a real determinism is by no means posited to disprove indeterminism.

18 Tegmark, “The Interpretation of Quantum Mechanics”, 855; Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 225; and Norsen and Nelson, “Yet Another Snapshot”, 6. It had the most votes in the 1997 and the 2011 polls.

19 “Although this is commonly attributed to Niels Bohr and frequently referred to as the ‘Copenhagen Interpretation’ in honor of the Dane, it is more correctly linked to the views of Werner Heisenberg—one of Bohr’s students” (Wegter-McNelly, *The Entangled God*, 104). For more details, see Howard, “Who Invented the ‘Copenhagen Interpretation?’”, 669, 677, 680.

20 See, Bohr, “The Quantum Postulate”, 586 and Heisenberg, *Physics and Philosophy*, 177.

21 Folse presents evidence that Bohr held to “entity realism” in the terminology of contemporary philosophy of science (Folse, “Niels Bohr, Complementarity, and Realism”, 96–105). Entity realism is skeptical about the truth of scientific theories concerning the realities they intend to describe but sees the implication of those realities in cause and effect relationships (e.g., in experiments) as justifying our belief in their objective existence.

22 The Copenhagen Interpretation makes no metaphysical claims about the relationship of observation to physical reality and does not claim that the wave function corresponds to something robustly and independently ontic.

In 1997 the “Many Worlds” interpretation was the second most preferred interpretation and in 2011 it was the third.²³ In 2013 no respondents indicated it is their favorite.²⁴ It is based on Hugh Everett’s “relative state” formulation of quantum mechanics in his 1957 doctoral dissertation.²⁵ According to current versions there is a universal wave function corresponding to the objectively existing real world that never collapses but only appears to do so through decoherence.²⁶ This results in the universal wave function splitting into alternate actual histories. Thus instead of the wave function really collapsing from many superimposed possibilities into one actuality every possibility is actualized, issuing in alternate histories within one “multiverse.”²⁷ The system exists in a real mixture of mutually exclusive superimposed actual—not merely possible—quantum states corresponding to the states perceived by observers. To observers only one actuality is realized in an apparently random collapse. Yet, since all actualities are realized the question of a collapse and the question of indeterminacy vs. determinism are moot. Indeterminacy and wave function collapse are observational artifacts, not actual realities, as the universal wave function remains in superposition and never really collapses. The universe “splits” because the mutually exclusive actualities do not overlap or communicate in any way.

“Pilot-wave” theories, formulated by Louis de Broglie²⁸ and later revived by David Bohm,²⁹ are highly controversial among physicists. A strongly opposed minority position, the “de Broglie-Bohm” interpretation does have a critical mass of staunch defenders.³⁰ In 1997, 8.3% claimed it as their preferred interpretation, 0% did so in 2011, and 63% did so 2013.³¹

This interpretation says the wave function corresponds to an objective physical system composed of particles which apparently but not actually collapses. Bohm’s version maintains that particles with properties (e.g., position and momentum) exist even when not observed. It sees the wave function as itself incomplete and so supplements it with a “guiding equation” for a “guiding wave” (or “piloting wave”). This determines the particles’ positions, which are “hidden” variables accounting for the causally determined measurement outcome.³² Since the wave function is an incomplete description of the system and the measurement outcome is causally determined there is no “measurement problem.” The universe is depicted

23 16.7% preferred the Many Worlds interpretation in 1997 (Tegmark, “The Interpretation of Quantum Mechanics”, 855) and 18% in 2011 (Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 225).

24 Norsen and Nelson, “Yet Another Snapshot”, 6. This is at least partly due to sampling bias.

25 The “Many Minds” and “Bare Theory” are two other interpretations based on Everett’s relative state formulation. For a history of the versions of Everett’s thesis and the surrounding debates, see, Osnaghia, Freitas, and Freire, “The Origin of the Everettian Heresy”, 97–123.

26 Decoherence involves the interaction of a theoretically isolated quantum state with its environment. Zeh first introduced decoherence in 1970 (Zeh, “On the Interpretation of Measurement in Quantum Theory”, 69–76). For an overview of more recent developments in environment-induced decoherence and superselection, see, Schlosshauer, “Decoherence, the Measurement Problem, and Interpretations of Quantum Mechanics”, 1267–1305.

27 This means that Schrödinger’s famous cat is simultaneously really dead and really alive, but in two different actual worlds within the one multiverse comprising all non-overlapping actual worlds.

28 See, de Broglie, “*La nouvelle dynamique des quanta*”, 105–132.

29 Bohm, “A Suggested Interpretation of the Quantum Theory in Terms of ‘Hidden’ Variables”, 166–179, 180–193.

30 See, e.g., Goldstein, “Bohmian Mechanics.”

31 Tegmark, “The Interpretation of Quantum Mechanics”, 855; Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 225; Norsen and Nelson, “Yet Another Snapshot”, 6. Again, the variance is probably due to methodological and sampling limitations. The 2011 poll report admits: “[T]he fact that de Broglie–Bohm interpretation did not receive any votes may simply be an artifact of the particular set of participants we polled” (Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 226). The 2013 report says its own results “demonstrate rather strikingly that the earlier conferences (i.e., 1997 and 2011) somehow failed to involve a rather large contingent of the broader foundations community. And similarly, the Bielefeld conference somehow failed to involve the large Everett-supporting contingent of the broader foundations community” (Norsen and Nelson, “Yet Another Snapshot”, 8).

32 “It is well known that the same empirical facts can either be understood in terms of an indeterministic theory (following Niels Bohr and his successors) or a deterministic theory (David Bohm). This dilemma has been resolved by almost all physicists through an appeal to the non-empirical criteria discussed earlier, for they judge the Bohm theory to display a degree of unnatural contrivance when compared with the development of conventional quantum mechanics. It remains instructive, however, to note that the controversy could not be settled on experimental grounds alone” (Polkinghorne, *Belief in God in an Age of Science*, 107–108).

by one wave function that never actually collapses but merely apparent collapse occurs in experimentally isolated subsystems represented by the Schrödinger equation plus a guiding equation. At measurement this “conditional wave function” transitions to a definite measurement outcome but, being causally determined, this is not an indeterministic jump.

Another interpretation is “Objective Collapse,” which came in second in 2013 at 16% and fourth in 2011 at 9%.³³ Here the wave function corresponds to an objectively real physical wave that actually collapses. The collapse is indeterministic since there are no hidden variables. Hence indeterminacy is metaphysical, not epistemic or semantic. The observer plays neither a formal nor physical role in the wave function’s collapse. This results in only one possibility being actualized and one unique history (not “many worlds”). The two main variants account for collapse by either altering the mathematical formalism³⁴ or identifying an external factor.³⁵

In 2011, 24% said “information-based / information theoretical” is their favorite interpretation and 76% said quantum information is a “breath of fresh air for quantum foundations.”³⁶ In 2013 only 5% said it is their favorite and only 15% agreed it is a “breath of fresh air.”³⁷

Information-based interpretations see the wave function as collapsing when information is recorded irreversibly in a measurement. Irreversibility is standard in quantum mechanics, as it incorporates the second law of thermodynamics, but there are epistemological and ontological understandings of the information. Mostly Copenhagen Interpretation-based, epistemological views say information is added to the observer’s mind only. This makes the wave function as a strictly mathematical entity collapse.³⁸ Ontological views³⁹ see the information as reified and independent of any observer, so the observer is unnecessary for the wave function’s collapse.

One well-worn interpretation in attempts to prove ontological intersubjectivity is the interpretation that attributes wave function collapse to consciousness. London and Bauer posited this early on.⁴⁰ A watershed for this interpretation was von Neumann’s analysis of the measurement problem.⁴¹ He labeled as arbitrary the separation or “cut” (*Schnitt*) between the observed system treated quantum mechanically and the observing system treated classically.⁴² This “cut” is necessary for the wave function’s collapse but its arbitrariness raises questions about the observed and observing systems’ separability from their environments and the rest of the world.

This means any measurement interaction involves a plethora of other measurements because the “cut” may be placed anywhere among all physical processes involved in the measurement.⁴³ Von Neumann describes the human observer’s subjective perception operative in measurement as *sui generis*. It is “extra-physical,” “a new entity relative to the physical environment and not reducible to the latter,” in the “intellectual inner life of the individual,” and “extra-observational.”⁴⁴ However, this extra-physical process

33 Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 225; Norsen and Nelson, “Yet Another Snapshot”, 6. In 1997 only 2% advocated this interpretation (Tegmark, “The Interpretation of Quantum Mechanics”, 855).

34 Ghirardi, Rimini, and Weber, “Unified Dynamics for Microscopic and Macroscopic Systems”, 470–491.

35 For Roger Penrose, the external factor is when space-time curvature (gravity) reaches a certain threshold (Penrose, *The Emperor’s New Mind*, 367–373). His proposal concerns general relativity in relationship to quantum theory.

36 Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 224, 225.

37 Norsen and Nelson 4, 6.

38 Heisenberg’s own view was that state reduction occurs when a measurement yields additional information. This brings about the sudden, discontinuous, change in the probability function from many variously valued probabilities to one certain value (Heisenberg, *Physics and Philosophy*, 54–55).

39 John Archibald Wheeler is the primary example. See, e.g., Wheeler, “Information, Physics, Quantum”, 354–358.

40 London and Bauer, “The Theory of Observation in Quantum Mechanics,” 217–259.

41 Von Neumann, *Mathematical Foundations of Quantum Mechanics*.

42 The reasons for this distinction were discussed above in footnote 5.

43 He uses the example of measuring a temperature: The measurement calculation can include the temperature measured by the thermometer, the mercury molecules, the observer seeing the mercury’s length, the light quanta reflected off the mercury column, their path into the observer’s eye, the light refraction on the eye’s lens, the image on the retina, the optic nerve and the brain, up to what is consciously perceived by the observer (Von Neumann, *Mathematical Foundations of Quantum Mechanics*, 419–420).

44 Von Neumann, *Mathematical Foundations of Quantum Mechanics*, 418–419.

of conscious perception is necessarily describable like any other reality in the physical world by assigning “to its parts equivalent physical processes in the objective environment, in ordinary space.”⁴⁵

Building on von Neumann’s work, some argue that the real boundary between the observer and the observed system is the observer’s extra-physical consciousness and this is what causes the wave function’s collapse. Eugene Wigner’s early view is representative:

The modified wave function is, furthermore, in general unpredictable before the impression gained at the interaction has entered our consciousness: it is the entering of an impression into our consciousness which alters the wave function because it modifies our appraisal of the probabilities for different impressions which we expect to receive in the future. It is at this point that the consciousness enters the theory unavoidably and unalterably. If one speaks in terms of the wave function, its changes are coupled with the entering of impressions from our consciousness.⁴⁶

Even if they consider differences in the interpretation of quantum mechanics, circumspect technical treatments can still give the impression that conscious observation is what causes the wave function to collapse. Being careful to explain various interpretations, Henry P. Stapp develops an evolving view of the role of consciousness in the wave function’s collapse and relates this to the philosophical mind–body problem.⁴⁷ Granting that the matter is far from settled,⁴⁸ Quentin Smith goes on to invoke Stapp’s view of the role of consciousness, buttressing his point by indicating how Stapp holds to the Copenhagen Interpretation:

We need to accept some interpretation of quantum mechanics, and on the standard (Copenhagen) interpretation Stapp correctly notes, I believe, that consciousness causes the physical state to collapse. Wigner in 1961 also realized, I believe, that the standard interpretation is led by the logic of its interpretation to the thesis that consciousness is the cause of the wave function collapse.⁴⁹

Appealing to Wheeler’s information-theoretical view, Lothar Schäfer argues that “The quantum phenomena make it possible to conclude that the basis of the material world is nonmaterial . . . and that elementary particles possess aspects of consciousness in a rudimentary way.”⁵⁰

Some appeal to Bohm’s description of “active information”⁵¹ and how particles have a “rudimentary mental pole” to argue for a fundamental mentality at the quantum level:

⁴⁵ This is the “principle of psycho-physical parallelism” (Von Neumann, *Mathematical Foundations of Quantum Mechanics*, 419).

⁴⁶ Wigner, “Remarks on the Mind-Body Question”, 289. See also, Wigner, *The Collected Works of Eugene Paul Wigner*, 34–36, 52–54, 67–68, 251–252, 255–257, 259; Heitler, “The Departure from Classical Thought in Modern Physics”, 194; and Heelan, “The Role of Consciousness as Meaning Maker in Science, Culture, and Religion”, 468. Wigner later abandoned this “consciousness causes collapse” interpretation (Wigner, *The Collected Works of Eugene Paul Wigner*, 240).

⁴⁷ In buttressing his argument that quantum mechanics involves consciousness, Stapp summarizes what he calls “four main interpretations” of quantum mechanics, spelling out how he sees consciousness as relating to each interpretation (Stapp, *Mindful Universe: Quantum Mechanics and the Participating Observer*, 119–120). Stapp has published much on this but *Mindful Universe* may be taken as representative.

⁴⁸ “Exactly how this universal application of quantum mechanics is explained depends on the interpretation of quantum mechanics one is using” (Smith, “Why Cognitive Scientists Cannot Ignore Quantum Mechanics”, 416).

⁴⁹ Smith, “Why Cognitive Scientists Cannot Ignore Quantum Mechanics”, 416. Careful to differentiate between measurement and consciousness in Von Neumann’s analysis of the measurement problem, Smith goes on to say that consciousness is still necessary: “On this standard interpretation ‘no consciousness’ implies ‘no collapse’ which implies ‘quantum physics is false’”. A basic axiom of physics (‘the projection postulate’) essentially includes psychological vocabulary” (Smith, “Why Cognitive Scientists Cannot Ignore Quantum Mechanics”, 418).

⁵⁰ Schäfer, “Quantum Reality”, 505. He cites Wheeler and Ford to the effect that “It is not unreasonable to imagine that information sits at the core of physics, just as it sits at the core of a computer. Information may not be just what we learn about the world. It may be what makes the world” (Wheeler and Ford 1998, 340)” (Schäfer, “Quantum Reality”, 509).

⁵¹ On the basis of what they dub “active information,” Bohm and Hiley argue: “It is thus implied that in some sense a rudimentary mind-like quality is present even at the level of particle physics, and that as we go up to subtler levels this mind-like quality becomes stronger and more developed . . . At each level, there will be a ‘mental pole’ and a ‘physical pole’. Thus as we have already implied, even an electron has at least a rudimentary mental pole, represented mathematically by the quantum potential” (Bohm and Hiley, *Undivided Universe*, 386–387).

The existence of rudimentary mindlike qualities at the quantum level of the implicate order and/or archetypal dimensions of the mind coextensive with the universe restores mind to its rightful place in a science in which the existence and significance of the ‘personal equation’ of the human observer must be accounted for.⁵²

Bohm also argued that consciousness is implied at the level of particle physics:

That which we experience as mind . . . will in a natural way ultimately reach the level of the wavefunction and of the “dance” of the particles. There is no unbridgeable gap or barrier between any of these levels. . . . It is implied that, in some sense, a rudimentary consciousness is present even at the level of particle physics. It would also be reasonable to suppose an indefinitely greater kind of consciousness that is universal and that pervades the entire process.⁵³

In this way some establish panpsychism on the basis of this purported role of consciousness. From two different interpretations biologist and doctor Stuart Kaufmann concludes:

We are led to the possibility of panpsychism, a conscious and ‘responsibly deciding’ universe by quantum variables upon measurement, and a ‘knowing’ quantum coherent state which is not conscious. Perhaps this all is a version of Wheeler’s Participatory Universe Observing Itself.⁵⁴

At the far extreme some accounts by personalities in popular culture and even scientists have pushed for something that approaches Berkeleyan idealism⁵⁵ in which something does not exist unless it is observed (*esse est principium*). Take physicist David Mermin’s statement:

Pauli and Einstein were both wrong. The questions with which Einstein attacked quantum theory do have answers; but they are not the answers Einstein expected them to have. We now know that the moon is demonstrably not there when nobody looks.⁵⁶

Very few physicists, though, accept this view that consciousness causes the wave function to collapse. In 2011 only 6% and in 2013 only 1% agreed that consciousness “plays a distinguished physical role (e.g., wave-function collapse by consciousness).”⁵⁷ This statement by a philosopher comports with the views of a great majority of physicists:

While it is understandable why it has become fashionable to connect quantum mechanics and consciousness, news of their impending marriage is greatly exaggerated. . . . it is implausible that consciousness enters into physics in the ways suggested by quantum mechanics-consciousness enthusiasts.⁵⁸

⁵² Todd, *The Individuation of God*, 81.

⁵³ Bohm, “A New Theory of the Relationship of Mind and Matter”, 131.

⁵⁴ Kauffman, “Beyond the Stalemate”, 167. See also, Kauffman, “Cosmic Mind?”, 36; Gao, “A Quantum Physical Argument for Panpsychism”, 59–70; and Brogaard, “In Search of Mentons: Panpsychism, Physicalism, and the Missing Link”, 140.

⁵⁵ David Ray Griffin discriminates between what some mean by Berkeleyan Idealism and what Berkeley actually meant. Those who speak of Berkeleyan Idealism may think “Berkeley held that we autonomously create the physical world” when he really meant “having sensory data impressed on our minds by God” (Griffin, *Unsnarling the World Knot*, 93).

⁵⁶ Mermin, “Quantum Mysteries for Everyone”, 397. After a detailed description of the physics of a dice roll onto a craps table, pop culture physicist and parapsychologist Evan Harris Walker states: “Only our observation of the object leads it to take on one out of all its possible orientations and come to rest with one of its six faces up” (Walker, “The Physics of Consciousness”, 270). Harris concludes: “We have seen matter and space as the natural consequence of nothing more than the fact that conscious observers exist” (Walker, “The Physics of Consciousness”, 331).

⁵⁷ Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 225; Norsen and Nelson, “Yet Another Snapshot”, 5. Some wrongly attribute this view to the Copenhagen Interpretation: “[V]ery few adhere to the notion that the observer plays a distinguished physical role (for example, through a consciousness induced collapse of the wave function). Given the relatively strong (42%) support for the Copenhagen Interpretation . . . this finding shows that support of the Copenhagen Interpretation does not necessarily imply a belief in a fundamental role for consciousness. (Popular accounts have sometimes suggested that the Copenhagen Interpretation attributes such a role to consciousness. In our view, this is to misunderstand the Copenhagen Interpretation.)” (Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 225).

⁵⁸ Loewer, “Consciousness and Quantum Theory”, 523.

There are many other interpretations.⁵⁹ Many physicists embrace the “instrumentalism” epitomized in the saying: “Shut up and calculate!”⁶⁰ This sees theories solely as instruments for coordinating experiences. Either theories do not intend to make claims about nature or their claims ought not be believed. Therefore instrumentalism eschews the whole project of coordinating quantum theory to reality by means of an interpretation of quantum mechanics.⁶¹

The goal here has not been to advocate particular answers to foundational questions or to advance any one interpretation of quantum mechanics. The aim has been to establish the fact that there is no consensus in the scientific community on these questions in the way there is consensus about the experimental procedure and mathematical formalism of quantum mechanics.⁶² In fact, there may even be more disagreement over foundational questions and interpretations than is commonly recognized.⁶³

4 Perils: Appeals to Interpretations of Quantum Mechanics

The rift between quantum mechanics *per se* and its interpretation should now be clear. Both academic and popular expositions have blurred this distinction, giving the impression that disputed positions support conclusions about ontological intersubjectivity ostensibly on the basis of quantum mechanics.⁶⁴ The scientific nature of quantum mechanics is thereby used to legitimate claims that are far from empirical and far from settled.⁶⁵

Methods for verifying scientific claims differ qualitatively from those used to answer quantum

59 These include: Consistent Histories; Ensemble/Statistical; Stochastic Mechanics; Modal; Relational Quantum Mechanics; and Quantum Logic. Some of these are not full-fledged interpretations but are regularly called such.

60 Frequently attributed to Richard Feynman, this famous imperative’s origins are debatable (Mermin, “Could Feynman Have Said This?”). The 2011 poll and the 2013 poll—which used the same questions as the 2011 poll—did not include instrumentalism as an option for a “favorite interpretation” (Schlosshauer, Kofler, and Zeilinger, “A Snapshot of Foundational Attitudes”, 226).

61 Tegmark remarks: “practical-minded experimentalists . . . typically show little interest in whether cozy classical concepts are in fact real in some untestable metaphysical sense or merely the way we subjectively perceive a mathematically simpler world where the Schrödinger equation describes everything—and they are therefore becoming less bothered by a profusion of worlds than by a profusion of words” (Tegmark, “The Interpretation of Quantum Mechanics”, 855).

62 “Although the formalism of quantum theory was well-established by the end of the 1920s, its character and consequences have remained subjects of investigation ever since and we have not yet attained a full understanding of all that is implied by it. . . the past forty years have seen many competing suggestions of alternative proposals. . . none is wholly satisfactory and the matter remains contentious and unsettled” (Polkinghorne, *Belief in God in an Age of Science*, 27–28).

63 The 2013 poll report concludes: “there is probably even significantly more controversy about several fundamental issues than the already-significant amount revealed in the earlier poll” (Norsen and Nelson, “Yet Another Snapshot”, 1).

64 If carefully qualified so as to preclude its *prima facie* meaning, talk of “creating properties” and “creating our world” could be acceptable instead of gross overstatement. Either way, left unqualified such talk can easily lead others to unjustified conclusions. One example of a popular treatment would be: “Philosophically, however, the implications of quantum mechanics are psychedelic. Not only do we influence our reality, but, in some degree, we actually *create* it” (Zukav, *The Dancing Wu-Li Masters*, 30) (emphasis Zukav’s). Some examples of scientists (but non-physicists) would be: “on the level of individual atomic processes the scientist now finds that he in fact has a role in the creation of the world he is describing” (Schlegel, “The Impossible Spectator in Physics”, 218); and “Thus, if we have free will our choice of experiment, and here our conscious observation of the electron, together with nature’s answer, ‘create’ reality” (Kauffman, “Beyond the Stalemate”, 161). Physicist Victor Stenger exposes how New Age gurus, books, media, and movies exploit quantum mechanics to claim that we create our own reality (Stenger, *Quantum Gods*, 35–48, 55–56). Burwell charts the exploitation and commercialization of quantum physics by the New Age movement (Burwell, “Figuring Matter: Quantum Physics as a New Age Rhetoric”, 344–366).

65 “It is instructive that the findings of quantum theory have been viewed as supporting a variety of worldviews. No one view of reality has cornered the market on quantum application. For this reason, to dogmatically assert that quantum physics ‘proves’ a particular scheme of reality is suspect. Quantum physics is still at the how and what stage. Useful facts are discovered (e.g., a neutron will decay radioactively in about seventeen minutes), but little is known about why these facts are true” (Brown, “Quantum Theology”, 486).

foundational questions, many of which are philosophical.⁶⁶ The upshot is a far greater consensus on quantum mechanics than on its interpretation. Ontological assertions predicated on interpretations are dubious in direct proportion to the disparity between the latter and the former. That some answers to foundational questions imply one another adds to their uncertainty.

Some do invoke specific interpretations of quantum mechanics without additional justification. To be sure, though, there are well-informed and well-reasoned arguments for specific ontological interpretations. These are questionable in direct proportion to the number of cases they must make for unequivocal answers to foundational questions. Competing answers to multiple foundational questions make the acceptance of any one such ontology more difficult.

For instance, Michael Epperson develops an elegant and cogent argument for an ontological interpretation that relies upon decoherence coupled with Heisenberg's view of superpositions as *potentia* and von Neumann's account of a quantum state's evolution. He does so in order to draw correlations with the concrescence of the actual entity in Whitehead's ontology.⁶⁷ Reviewing Epperson's project, Henry Folse writes: "While Epperson's exposition of the formalism is cleverly presented . . . his exposition of the various interpretative stances taken toward it is less clear. . . . debates over these questions are far from reaching any consensus."⁶⁸

While it may be impossible to avoid foundational questions entirely, unanimity concerning quantum mechanical experimental procedure makes conclusions about reality drawn from the latter while striving to avoid the former more tenable. We now proceed to the part of this essay's thesis that proposes there are basic facts about quantum mechanical experiments themselves that unreflectively suggest a primitive ontology of interrelational intersubjectivity.

5 Promises: A basic ontology of intersubjectivity

Can we infer that intersubjectivity is ontologically basic from quantum mechanics alone? Yes, a minimalist approach can infer from the facts of the experimental procedure and mathematical formalism that experience, subject-like activity, relationship, and event are primitive ontological notions. In a display of self-exemplification, these notions also implicate each other.

Experience is the ultimate fact in quantum mechanics. Even if observers do not determine what they observe, obtaining values for a system's initial state representation and later measurement rely upon experience. Regardless of how differently they understood what they were doing, the pioneers of quantum mechanics agreed that it was about experiences and their correlations.⁶⁹

Independent of observation, measurement of an observable's value is itself experiential in some sense. This does not mean the measurement apparatus exhibits mental activity. It simply refers to the empirical fact that whenever material entities encounter one other they react in a way analogous to experiential contact. One father of modern scientific method, Sir Francis Bacon, pointed to the ubiquity of this phenomenon in nature:

⁶⁶ There is also the question of what motivates appeals to or arguments for a particular interpretation: "Debates about the foundations of quantum mechanics are sometimes perceived as an ideological battle where the objectivity of the scientific enterprise succumbs to philosophical and personal preferences" (Schlosshauer, Kofler, and Zeilinger, "A Snapshot of Foundational Attitudes", 226).

⁶⁷ Epperson, *Quantum Mechanics and the Philosophy of Alfred North Whitehead*.

⁶⁸ Folse, "Review of *Quantum Mechanics and the Philosophy of Alfred North Whitehead*", 495. Epperson's criticism of Bohr for treating the measurement apparatus as a classical system is also questionable. See footnote 5.

⁶⁹ "We meet here in a new light the old truth that in our description of nature the purpose is not to disclose the real essence of the phenomena but only to track down, as far as it is possible, relations between the manifold aspects of our experience" (Bohr, *Atomic Theory*, 18). Bohr repeatedly speaks of the "ordering of our experiences" (e.g., Bohr, *Atomic Theory*, 1, 4, 92, 98). Von Neumann wrote: "Indeed, experience only makes statements of this type: an observer has made a certain (subjective) observation and never any like this: a physical quantity has a certain value" (von Neumann, *Mathematical Foundations of Quantum Mechanics*, 420).

It is certain that all bodies whatsoever though they have no sense have perception: when a body is applied to another there is a kind of election to embrace that which is agreeable and to exclude or expel that which is ingrate: and whether the body be alterant or altered, evermore a perception precedes operation; for else all bodies would be like to another. And sometimes this perception in some kind of bodies is far more subtle than sense, so that sense is but a dull thing in comparison of it: we see a weatherglass will find the least difference of the weather in heat or cold when we find it not. And this perception is sometimes at a distance, as when a loadstone draweth iron, or flame of naphtha of Babylon, a great distance off. It is therefore a subject of a very noble inquiry to enquire of the more subtle perceptions for it is another key to open nature . . . and sometimes better.⁷⁰

Bacon—who was no metaphysician—bound himself to a strictly experimental method with attention to “irreducible stubborn facts” and an “inductive method of eliciting general laws.”⁷¹ Nonetheless he saw in nature what he called “perception.”⁷² Bacon is saying there are at least some subjective aspects of physical reality, not like human subjectivity but a degree of subjectivity nonetheless.⁷³ “Panexperientialism” is a better descriptor here than “panpsychism.”⁷⁴

Again, the fringe interpretation in which consciousness causes the wave function’s collapse is sometimes presented as definitive. Like all interpretations of quantum mechanics, this position implies debatable answers to foundational questions. A more philosophically parsimonious explanation will speak of “subject-like activity” and an observing system’s “participation.” But this “subject-like activity” is not limited to human observers. As aforementioned, “measurement” simply means the interaction between the measuring apparatus treated as a classical system and the measured quantum system, independently of any human observer.

Disregarding disquisitions on why, it is a fact that when a quantum system is unobserved the wave function continues to evolve deterministically with superpositions of mutually exclusive possibilities but upon measurement collapses into one actuality. This means the observing system is bound up with the observed system’s actuality at measurement.⁷⁵ There is a connection between the observing system’s activity and what the observed system becomes. At the very least we may say that a seemingly passive physical reality is really active through subject-like “measurement” activity that is related to the essential becoming of an entity objective to itself.

Additionally, the fact that it is impossible to definitively measure position and momentum simultaneously dismantles the classical concept of a “particle” in motion, which requires both.⁷⁶ It is impossible to have a complete description of the observed system because complementary properties stand in inverse relationship. If it lacks properties essential to a classical object then it is not a classical object. Choice of experimental conditions determines what “properties” will be observed. This dependency means the properties are of a piece with both the measuring apparatus and the observer who chose the setup. All

⁷⁰ Bacon, *Natural History*, Section IX, quoted in Whitehead, *Science and the Modern World*, 41–42.

⁷¹ Whitehead, *Science and the Modern World*, 42.

⁷² “Bacon discriminates between *perception*, or *taking account of*, on the one hand, and *sense*, or *cognitive experience*, on the other hand” (Whitehead, *Science and the Modern World*, 42) (emphasis Whitehead’s).

⁷³ Bacon’s insight was eclipsed by what became the dominant modern scientific view of matter as wholly vacuous and inert, passively operated upon by external forces. Whitehead concludes: “I believe Bacon’s line of thought to have expressed a more fundamental truth than do the materialistic concepts which were then being shaped as adequate for physics. We are now so used to the materialistic way of looking at things . . . that it is with some difficulty that we understand the possibility of another mode of approach to the problems of nature” (Whitehead, *Science and the Modern World*, 42).

⁷⁴ Panexperientialism “holds that this diminishing of the complexity of experience continues down through plants, and through to the basic constituents of reality, perhaps electrons and quarks. If the notion of ‘having experience’ is flexible enough, then the view that an electron has experience—of some extremely basic kind—would seem to be coherent” (Goff, Seager, and Allen-Hermanson, “Panpsychism”).

⁷⁵ One need not speak of “causation. It is further bound to subsequent realities because when the wave function collapses its now settled actuality affects the probabilities for the results of subsequent measurement interactions.

⁷⁶ “[I]f we never actually determine more than one of the two properties (possession of a definite position and of a definite momentum), and if when one is determined we can make no assertion at all about the other property for the same moment, so far as our experiment goes, then we are not justified in concluding that the ‘thing’ under examination can actually be described as a particle in the usual sense of the term. We are equally unjustified in drawing this conclusion even if we can determine both properties simultaneously, if neither can then be determined exactly” (Born, *Atomic Physics*, 96–97).

of this points to fact that both the measuring apparatus and the observing subject are not utterly passive but rather active agents.

This also means the observed system is relationally constituted. The observed phenomena associated with the observed system are indivisible from the measuring apparatus.⁷⁷ Bypassing attempts at further explanation, at a minimum we must say there is a correlation between antecedent observer choice of experimental setup, measuring apparatus, and the subsequent observable. A correlation is a relationship and so correlated experiences are in relationships.

Measurement implies an interaction between the experiencing measuring apparatus⁷⁸ and the experienced system. This interaction is a relationship and so again measurement itself is an experiential relationship. Within this measurement interaction relationship neither what is experienced phenomenally nor what is experiencing is independent.⁷⁹

Moving to the mathematical formalism, we can say the formalism itself depicts a correlation of experiences. Values obtained for the observed system's initial state representation and the observable's value at measurement both require experience. Even apart from the requisite experiences to obtain them, none of the mathematical values is isolated from the others. The formalism is constructed around the relationship between the initial and final values, and the evolution of the system state according to the wave function relates all values in the state representation. The wave function depicts a deterministically evolving development of values for probabilities of possible measurement outcomes prior to measurement. At measurement one probable value becomes the actual value, upon which basis the wave function's further deterministic evolution proceeds. The measured value thus stands in causal relationship to all later values.

A minimalist description, then, will not speak of a "particle" as a "thing" but rather in terms of relationships of correlation. This set of relations is expressed mathematically in its wave function. Since some but not all "properties" needed to categorize physical bodies in classical physics obtain, the particle is not an independently existing object in the classical sense.⁸⁰ Its "being" is through and through relational.⁸¹ Nothing in either the procedure or math taken only by itself exists in isolation.⁸² "Relation," then, is ontologically basic in quantum mechanics while classical "substance" metaphysics is excluded.⁸³

Quantum mechanics reveals yet another elementary fact: Events are ontologically fundamental. In the original nonrelativistic formalism, calculations concern only one particular instant in time; they take place only "in the instant."⁸⁴ Measurement interactions are punctiliar and discrete. Actuality is restricted to

77 "In the proper quantum effects, we have to do with phenomena where no sharp separation is possible between an independent behaviour of the objects and their interaction with the measuring agencies necessary for the definition of the observable phenomena" (Bohr, *Foundations*, 1). See also, Bohr, *Foundations*, 19, 25, 210, and 224.

78 "Experiencing" is used in the sense explained above, which most do not automatically take to be its connotation.

79 "[A]ny observation of atomic phenomena will involve an interaction with the agency of observation not to be neglected. Accordingly, an independent reality in the ordinary physical sense can neither be ascribed to the phenomena nor to the agencies of observation" (Bohr, "The Quantum Postulate", 580).

80 "But one should not imagine that there is anything of the nature of matter actually rotating. The idea of spin without the existence of something spinning seems rather abstruse. But one should remember that there are other examples of such abstractions" (Born, *The Restless Universe*, 206).

81 "[A]n elementary particle is not an independently existing, unanalyzable entity. It is, in essence, a set of relationships" (Stapp, "S-Matrix Interpretation of Quantum Theory", 1303).

82 "[N]ot a structure built out of independently existing unanalyzable entities, but rather a web of relationships between elements whose meaning arise wholly from their relationships to the whole" (Stapp, "S-Matrix Interpretation of Quantum Theory", 1303).

83 For Aristotle, "substance" (*ousia*) is the first category of existence and its salient feature is independence. A substance has a "separate existence" (Aristotle, *Metaphysics*, 1042a24–31) and is "that which is neither said of a subject nor in a subject" (i.e., a quality [*poion*], property, trait, attribute, accident, or part) (Aristotle, *Categories*, 2a11–15; cf. 1b4). Comporting with the early modern turn to epistemology, modern philosophy's definition is more thought-based, e.g., a "substance" is that which is "in itself and is conceived through itself: in other words that of which a conception can be formed independently of any other conception" (Spinoza, *Ethics*, Part 1, Definition 3).

84 "The original formulation of quantum theory deals with operations at the moment. It is fundamentally nonrelativistic therefore, as has been pointed out from the start" (Finkelstein, "Physical Process and Physical Law", 184).

events and does not include what happens between them.⁸⁵ “Properties” emerge and are recorded only at the point of measurement, a discrete instant.⁸⁶

In summary, prescind from controverted foundational questions we may say that, experience, subject-like activity, essential relationality, and event are basic in quantum mechanics. Evident without much abstractive reflection, these together form the rudiments of an ontology of intersubjectivity. A minimalist explication of quantum mechanics’ bare facts reveals that reality consists of subject-like and event-like simple experients in myriads of constitutive relationships.

6 Prospects for future acts of interpretation

This analysis has striven to avoid posing assumptions about and drawing conclusions from the foundational questions that occupy the various interpretations of quantum mechanics. If the work of interpretation is deemed desirable, worthwhile, or even necessary, however, then the question arises as to whether any existing speculative philosophy can accommodate the intersubjective ontological elements revealed by the basic facts of quantum mechanics. We close by summarily noting a few points to commend the philosophy of Alfred North Whitehead in this regard,⁸⁷ starting with how in what has been called a “radical empiricism” Whitehead is adamant that both science and metaphysics must be based upon experience of the particularity of the ultimate agents of “stubborn fact” in their full concreteness.⁸⁸

Whitehead argues against the modern materialist notion that the fundamental constituents of nature have properties referring to both space and time, which he designates the “fallacy of simple location.”⁸⁹ Opposing what he dubs “vacuous actuality,” he attributes primitive experience to reality’s building blocks⁹⁰ and indeed takes experiential immediacy to be the essence of being.⁹¹ If we resist abstraction from our immediate experience then there is no other location for the unity that marks being than experience itself.⁹² This ontologically fundamental experience comes in discontinuous, irreducible, quanta-like buds or drops.⁹³

⁸⁵ “[T]he probability function does not allow a description of what happens between two observations. Any attempt to find such a description would lead to contradictions; this must mean that the term ‘happens’ is restricted to the observation” (Heisenberg, *Physics and Philosophy*, 52).

⁸⁶ “The fact that an electron has no definite path means that it has also, in itself, no other dynamical characteristics . . . [they] appear only as a result of the measurement itself” (Landau and Lifshitz, *Quantum Mechanics*, 2–3). “Quantum fluctuations,” or the popping in and out of existence of virtual particle-antiparticle pairs, also point to an event-like ontology.

⁸⁷ There has been copious discussion of Whitehead and quantum mechanics. Just a few examples are: Shimony, “Quantum Physics and the Philosophy of Whitehead”, 240–261; Folse, “The Copenhagen Interpretation of Quantum Theory and Whitehead’s Philosophy of Organism”, 189–199; Stapp, “Whitehead, James, and the Ontology of Quantum Theory”, 83–109; Riggan, “Quantum Physics and Freedom in a Whiteheadian Perspective”, 255–265; Malin, “Whitehead’s Philosophy and Quantum Physics”, 17–74; Griffin, “Bohm and Whitehead on Wholeness, Freedom, Causality, and Time”, 165–191; McHenry, “Whitehead, Quantum Mechanics and Local Realism”, 164–170; Eastman and Keeton, *Physics and Whitehead*; Epperson, *Quantum Mechanics and the Philosophy of Alfred North Whitehead*; Epperson and Zafiris, *Foundations*; Bagci, “Ghirardi-Rimini-Weber Collapse Theory and Whiteheadian Process Philosophy”, 368–393; Athearn, “Physics and Whitehead: An Alternative Approach”, 80–90; and Bansal, “Whitehead’s Cosmology—Process Relational Perspective to Relativity and Quantum Mechanics”, 27–39. There are numerous others.

⁸⁸ Whitehead, *Science and the Modern World*, 42–44, 135, 145; and Whitehead, *Process and Reality*, 4–5, 13, 17, 117, 145–146. Whitehead says that “the philosophy of organism—as it should—appeals to the facts” (Whitehead, *Process and Reality*, 117).

⁸⁹ Whitehead, *Science and the Modern World*, 49, 58.

⁹⁰ Whitehead, *Process and Reality*, xiii, xxii, 29, 167, 190.

⁹¹ “[A]part from the experiences of subjects there is nothing, nothing, bare nothingness” (Whitehead, *Process and Reality*, 167); and “the whole universe consists of elements disclosed in the analysis of the experience of subjects” (Whitehead, *Process and Reality*, 166). He means “experience” in the broader sense covered above.

⁹² “The consideration of experiential togetherness raises the final metaphysical question: whether there is any other meaning of ‘togetherness.’ The denial of any alternative meaning, that is to say, of any meaning not abstracted from the experiential meaning, is the ‘subjectivist’ doctrine” (Whitehead, *Process and Reality*, 189). “One” or unity is a traditional transcendental predicate of being.

⁹³ Whitehead, *Process and Reality*, xii–xiii, 50, 68. See also, Whitehead, *Science and the Modern World*, 135.

With his “subjectivist principle” Whitehead repudiated the subject-predicate form of expression in philosophical descriptions of reality and its correlative concept of substance with accidental qualities or attributes.⁹⁴ Being is never merely objectively given but is always attendant upon and referable to subjectivity.⁹⁵ Hence, the fundamental ontological constituents of reality are distinct quanta of subjective experience, not “substances” with persistent qualities perduring across time.⁹⁶ Whitehead calls these “actual entities” or “actual occasions.”⁹⁷

Whitehead’s explanation of the genetic analysis of the actual entity is extensive⁹⁸ but we may note some key points. “Eternal objects” as the potential forms of definiteness that an actual entity can assume⁹⁹ are comparable to the superimposed probabilities of all possible but not necessarily compossible states in the probability wave before the state reduction; and the “cutting off” and “abrupt synthesis” of potentialities resulting in what “becomes” (the process is atemporal) the actuality parallels quantum state reduction.¹⁰⁰

“Relation” is basal for Whitehead as actual entities are relationally constituted. Sharply diverging from the classical concept of “substance” with purely external relations nonessential to its being, Whitehead avers that an entity has “internal relations” with other—indeed all other—entities whereby the latter become ontologically constitutive of the former.¹⁰¹ Whitehead’s neologism “prehension” expresses this fact,¹⁰² and additionally connotes the activity associated with subjectivity inasmuch as a prehension is an “uncognitive apprehension.”¹⁰³

In another display of the obviation of the classical subject–object dichotomy, Whitehead’s “principle of relativity” conveys how once a novel actual entity emerges as a constellation of relationships with every already existing entity it becomes a potential element for inclusion in the relational constitution of all successive entities.¹⁰⁴ The principle of relativity evinces real intersubjective causality: Every existing entity conditions a novel entity as its “cause” and once actual, a novel entity becomes a causal datum conditioning all subsequent entities as “effects.”¹⁰⁵

In summary, for Whitehead reality is through and through event-like, panexperiential, intersubjective, and relational. The primitive ontological notions intrinsic to quantum mechanics are equally fundamental in Whitehead’s speculative scheme.

⁹⁴ Whitehead, *Process and Reality*, xiii, 21, 29, 79–80, 157–167.

⁹⁵ He lauds modern philosophy’s “turn to the subject” beginning with Descartes but faults Descartes and his successors for not applying the subjectivist principle to the whole of reality. He likewise criticizes Kant and Kant’s successors for allowing this residual objectivism to insert an insuperable gap between the subject and the object *per se* (Whitehead, *Process and Reality*, xi, 71–72, 79–80, 157–160, 167, 189–190, 325).

⁹⁶ “Substance” is a pragmatically useful concept but mistaken if viewed as a statement about the nature of things (Whitehead, *Process and Reality*, 79). “Objects” are abstractions from events (Whitehead, *The Concept of Nature*, 125). Assigning them to reality is the “fallacy of misplaced concreteness,” or reifying an abstraction (Whitehead, *Science and the Modern World*, 51).

⁹⁷ Whitehead, *Process and Reality*, 18, 22, 80, 128–129, 245. This ultimacy of experience is on display in how Whitehead forges technical metaphysical terms from the commonsense vocabulary of subjective experience. Everyday terms like “memory,” “feeling,” “lure,” “aim,” “decision,” and “satisfaction” become ontological nomenclature.

⁹⁸ See, Whitehead, *Process and Reality*, 219–280 (Part III).

⁹⁹ Whitehead, *Process and Reality*, 22–23, 39–40, 44, 60, 184, 188, 214, 290–291.

¹⁰⁰ Whitehead, *Science and the Modern World*, 176; and Whitehead, *Process and Reality*, 19, 23, 32, 40–46, 88, 150, 185, 221–222, 234, 239–256. Again using subjective terminology, Whitehead calls this a “decision” which, according to its Latin etymology (*decido*), means “to cut off” (e.g., Whitehead, *Process and Reality*, 42–43).

¹⁰¹ “When we understand the essences of these things, we thereby know their mutual relations to one another” (Whitehead, *Adventures of Ideas*, 112). See also, Whitehead, *Process and Reality*, 22, 59–60.

¹⁰² See, Whitehead, *Science and the Modern World*, 69, 148; Whitehead, *Process and Reality*, 18–20, 22–24, 52, 235–280; and Whitehead, *Adventures of Ideas*, 176, 180, 226, 230–234.

¹⁰³ Whitehead, *Science and the Modern World*, 69.

¹⁰⁴ The “principle of relativity” states that “the potentiality for being an element in a real concrescence of many entities into one actuality is the one general metaphysical characteristic attaching to all entities . . . and that every item in the universe is involved in each concrescence” (Whitehead, *Process and Reality*, 22).

¹⁰⁵ Whitehead, *Process and Reality*, 236. Real causality is a cardinal doctrine for Whitehead and integral to his metaphysics. He all but excoriated Hume and Kant for their treatments of causation. This goes beyond the minimalist ontology derived from quantum mechanics in this essay. For Kant’s influence on Bohr, see Chevalley, “Niels Bohr’s Words and the Atlantis of Kantianism”, 33–55.

7 Conclusion

This essay has argued that appeals to interpretations of quantum mechanics for an ontology of intersubjectivity are significantly weakened by the disputed status of those interpretations but a minimalist examination of quantum mechanics based on what is agreed upon does discover basic ontological features that can serve metaphysical projects wanting to use quantum mechanics as a resource. These include experience, subject-like activity, relationship, and event. Taken together, these point to reality as fundamentally intersubjective and interrelational. Because it provides a similar picture of reality with the same ontological elements, the philosophy of Alfred North Whitehead is a ready resource for those who do judge the interpretation of quantum mechanics to be a worthwhile, or even necessary, undertaking. Therefore, notwithstanding the perils to be avoided in doing so, there is in fact promise for Christian theological discussions of the God–world relationship that, seeking to ground metaphysics in the physical sciences, adduce quantum mechanics for an ontology of interrelated intersubjectivity.

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