Quantum Metaphysics: A New Paradigm?

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The discovery of quantum mechanics has had a significant impact on physics and other sciences, but its important influence on metaphysics has been inadequately explored. Previously, quantum mechanics has been interpreted by some philosophers as a justification for previous positions or as a re-interpretation of already existing ideas. In discussing the possible influence of quantum mechanics on metaphysics, this paper gives particular consideration to the Uncertainty Principle of Werner Heisenberg and the wave mechanics of Erwin Schrödinger, and their impact on the ideas of several modern philosophers including Ernst Cassirer, who was unusual in his early recognition of the need to re-interpret reality in light of these developments. This paper sets the historical background, explains the relationship between metaphysics and classical, Newtonian mechanics, and examines various steps in the discovery of quantum mechanics which highlight points relevant to metaphysical theories. This is followed by analyses of specific topics in metaphysics and the impact that the discovery of quantum mechanics has had on them, concluding with suggestions for further interdisciplinary approaches to reality, determinism and causality.

Keywords: Quantum mechanics; metaphysics; determinism; causality; reality

1. Introduction

Philosophy and natural science were both strongly influenced in the seventeenth century by the success of such mathematical techniques as deduction from "self-evident" axioms according to fixed rules, *a priori* methods, *et cetera*. In the eighteenth century, the mechanical model, particularly that of the Newtonian system, came to dominate. As Cassirer noted[1], Immanuel Kant believed that Newton's system provided him with a fixed code of physical "truth" and that philosophical knowledge could be definitively grounded on the "*factum*" of mathematical natural science. Kant also endorsed the idea that metaphysical speculations could be guided by data arising from "the mathematical consideration of motion in connection with knowledge of space"[2]. In the twentieth

[1] Ernst Cassirer, *Substance and Function. Einstein's Theory of Relativity*, pp. 352-353.
[2] Immanuel Kant, *Attempt to Introduce the Concept of Negative Magnitudes into Philosophy*, (1763); quoted in *Op Cit*, p. 351

century, however, a new model arose and philosophers have now to take into account not only Einstein's Special and General Theories of Relativity but especially Quantum Mechanics.

2. Metaphysics and Classical Physics

A common metaphysical assumption in science is empirical consistency, reflected in the expectation that identical experimental systems should, statistically, always produce the same observations. In the deterministic "Newtonian" world space and time are absolute, all motion has a cause, and nothing is uncertain. As Werner Heisenberg stated in a lecture delivered at Vienna University in 1935, classical physics is based on a system of mathematically concise axioms and therefore the validity of classical physics appears to be absolute[3]. However, this "absolutist" view of the world has been seriously undermined by developments in modern physics. There had been doubt of its infallibility even earlier. In his pamphlet *The Analyst*, George (Bishop) Berkeley questioned "whether the object, principles, and inferences of the modern Analysis are more distinctly conceived, or more evidently deduced, than religious Mysteries and points of Faith." Indeed, confidence in the certainty of mathematics and natural sciences was undermined long before the advent of quantum mechanics. For example, analyses of Euclid's postulate concerning parallel lines cast doubt upon the truth and perfection of Euclidean geometry and Kant pointed out that, while two triangles equal in all respects are congruent in plane geometry, they are not necessarily so on the surface of a sphere[4]. With the invention of non-Euclidean geometries and with the paradoxes of the infinite discovered by George Cantor, faith in the truth and infallibility of mathematics was further weakened. For Ernst Cassirer, the axioms of geometry are never given or realized in experience and therefore can be neither validated or invalidated by experience nor derived from physical reality. The axioms must be constructed independently of physical reality and refer to possibilities only.[5]

According to classical physics, motion (and acceleration) of matter 'particles' occurred in a framework of absolute time and space and, in this framework, matter did not affect space[6]. Ernst Mach[7]

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[3] Werner Heisenberg, *Philosophic Problems of Nuclear Science*, p. 41.

[4] Immanuel Kant, *Prolegomena*, §13, 285-286

[5] Ernst Cassirer, "The Concept of Group and the Theory of Perception", p. 18.

[6] Although Newton was in some measure forced into an "absolutist" position when formulating his laws of dynamics, he included, as the fourth law in his original formulation of his laws of motion, the Galilean principle of relativity. This law was not included in his final version in the *Principia* since he had come to realize that his, now famous, three laws of motion were sufficient for deriving all the others. Newton used the notion of "absolute space" in the description of his laws of motion merely to render more precise the framework in which the laws applied. (Cf. R. Penrose, *The Road to Reality*, p. 388.)

[7] Ernst Mach, *The Science of Mechanics, A Critical and Historical Account of Its Development*, Open Court Publishing, 1960,

postulated that one should speak of acceleration relative to the distant stars rather than speaking of the acceleration of a mass relative to absolute space, thereby implying that the inertia of a body is influenced by far distant matter. This view had a considerable influence on Albert Einstein and, in particular, on the development of his theory of general relativity. Einstein rejected the 'particle' conception of matter and held that matter does affect space because matter and space are united; that is, matter is spherically spatially extended.

3. Quantum Mechanics[8]

According to the double slit experiments of Young and colleagues, light possesses wave properties, but the evidence also demonstrated that light behaves like particles. In order to resolve the contradiction between the theoretical description of emission of light and the experimental evidence, Planck postulated in 1900 that light is emitted in quanta of energy and that there is a proportionality factor, $\hbar$, between the frequency of a wave and the minimum chunk of energy it can have. In 1923, Louis de Broglie suggested that wave-particle duality applied not only to light, but also to matter as well. He showed that the frequency of matter waves is proportional to Planck's constant $\hbar$. Erwin Schrödinger suggested that the waves were "smeared-out" electrons, but Max Born redefined Schrödinger's electron wave by suggesting that it must be interpreted from the standpoint of probability.

Meanwhile, in 1925, Werner Heisenberg was attempting to find a way to connect the quantum numbers and energy states in an atom with the experimentally determined frequencies and intensities of the light spectra. According to classical physics, he should have been able to solve the equation of motion using the quantities such as the linear momentum (**p**) and the displacement from the equilibrium (**q**) to calculate the energy of the particle in the state **n**. Instead, he found that he had to include the *quantum postulate* as Niels Bohr had done in his analysis of atomic structure, because unlike classical theory, in quantum theory $\mathbf{pq} \neq \mathbf{qp}$. Max Born realized that Heisenberg's symbolic multiplication was matrix calculus. Heisenberg's quantum matrix theory resulted in his realization that no analogy could be drawn between atomic structure and the structure of the classical world.

Schrödinger intended his theory of matter waves to have the same relationship to mechanics that Maxwell's theory of electromagnetic waves had to optics. He believed that his discovery was a return to physics based on continuum processes and he proposed that wave motion was the source of all physical reality. He tried to describe all particles as the superposition of waves but this was soon

[8] Most of the scientific facts in this section are based on those presented in *Introducing Quantum Theory* by J. P. McEvoy and Oscar Zarate.

challenged by Henrik Lorentz who pointed out that the wave function spreads as time increases and that Schrödinger's discoveries could not fit into the classical framework. Schrödinger then began to compare his wave function theory with Heisenberg's matrix mechanics and found that they were equivalent from a mathematical point of view, despite the fact that his theory was based on a clear conceptual wave model of atomic structure while Heisenberg viewed such a model as meaningless.

In 1926, Born presented a paper on collision phenomena in which he introduced the quantum mechanical probability. He had found a method to reconcile particles and waves by introducing the concept of probability. Schrödinger's wave function, Ψ, determines the probability that a particle will be in a particular position, but unlike the electromagnetic field, Ψ has no physical reality. Shortly after this, Born stated that the probability of the existence of a state is given by the square of the normalized amplitude of the individual wave function (that is, by Ψ^2), thereby showing that there are no precise answers in atomic theory, there are only probabilities. In 1927, Heisenberg discovered that there is no method for determining both the exact position of a sub-atomic particle and the particle's exact momentum simultaneously (Heisenberg, 1927:174-5). This gave rise to the Heisenberg Uncertainty Principle which is that, in a simultaneous measurement of momentum and position, the uncertainty is always greater than a fixed amount which is approximately equal to Planck's constant $\hbar$. The Uncertainty Principle had serious consequences for beliefs in determinism.

Niels Bohr created a consistent whole by combining Born's probability interpretation of Ψ with other aspects of quantum mechanics, including Heisenberg's Uncertainty Principle and matrix mechanics, and his own *Principle of Complementarity*, according to which both wave and particle behaviour are necessary for a full understanding of the properties of an object. He concluded that the description of an atomic system before measurement, is **undefined** and has only the potential of certain values with certain probabilities. This collection of ideas is known as the *Copenhagen Interpretation* (CHI). The Copenhagen Interpretation does not provide any indication of what a quantum object might be and Einstein felt that the CHI was temporary and had only heuristic value; he sought a theory that could describe the "thing-in-itself" rather than only the probability of its occurrence. For supporters of the CHI, it was meaningless to search for the "thing-in-itself" since information about a quantum object only comes from experiment as nothing can be known about a quantum object without measurement. Some went even further by claiming that, in some sense, a quantum object does not exist when it is not being measured. While this extreme view is not widely accepted, CHI does assert, as Bohr reminded Einstein in response to his "EPR paradox" challenge in 1935, that quantum mechanics forbids any separation between the observer and the observed. The observer and the quantum objects being observed are part of a single system; there is no independence of between the observer and what is observed.

Einstein spent a considerable part of his later years attempting to develop a unified field theory which accommodate both relativity and quantum mechanics. Unfortunately for Einstein, the Uncertainty Principle definitively undermined any attempt to develop a framework close to that of classical physics. During the 1970s and 1980s, physicists who continued to search for a “unified field theory” developed a new model called “string theory”. String theory has proved successful, to a certain extent, in providing a mathematical model that integrates the strong and the weak nuclear forces, electromagnetism, and gravitation. But these developments pose serious challenges to previous ways of seeing the universe. String theory postulates a universe composed of “loops of strings and oscillating globules, uniting all of creation into vibrational patterns that are meticulously executed in a universe with numerous hidden dimensions capable of undergoing extreme contortions in which their spatial fabric tears apart and then repairs itself.”[9] Studies in M-theory, which unites five previous string theories into an over-arching framework, appear to show that there may possibly be domains in which there is no notion of time or space at all.

4. Metaphysics after Quantum Mechanics

In his discussion of “Recent Changes in the Foundations of Exact Science”, Heisenberg pointed out that the effects of the transformations of the foundations of exact science were not limited to their influence on technical and experimental research. He went on to state that these effects were starting to be felt in the field of the philosophical theory of perception since quantum mechanics undermines both the concept of absolute time and Euclidean space, and also the laws of causality.[10] For instance, the Uncertainty Principle, according to which causal laws are suspended at the quantum level, has been used to refute Kant’s claim that the category of cause and effect is a necessary condition of experience[11].

One solution to the effect of quantum mechanics on metaphysics is to eliminate metaphysics altogether by declaring it to be “meaningless”. The positivists, who were anti-realists concerning "theoretical entities", attempted to produce a science without metaphysics by prohibiting

[9] Brian Greene, *The Elegant Universe*, pp. 386-387.
[10] W. Heisenberg, *Philosophic Problems of Nuclear Science*, pp. 20-21
[11] I. Kant, *Critique of Pure Reason*, A 188/B 234

unobservables. In his *Language, Truth, and Logic*, A. J. Ayer explicitly defends a version of phenomenalism which is not very different from that of Berkeley. He held that one can generally distinguish between observational and theoretical kinds of vocabulary, where observational terms correspond to particular experiences (or “sense-data”), and theoretical terms only acquire meaning by being defined in terms of observation terms. Thus, for Ayer, a theoretical term such as “electron” would refer to a “logical construction” from experience[12].

The anti-metaphysical stance of the positivists is no longer widely held. Rudolf Carnap attempted to show that the demarcation between science and metaphysics coincides with that between sense and nonsense. In his criticisms of Carnap’s position, Karl Popper pointed out that the positivists’ conception of ‘meaning’ or ‘sense’ is not an appropriate demarcation between science and metaphysics; metaphysics not being a science does not necessarily render it meaningless. Popper stated that demarcation by meaninglessness tends to be simultaneously *too narrow and too wide* in so far as it has inadvertently excluded some scientific theories as meaningless, and yet failed to exclude ‘rational theology’.[13] If the positivists’ position is rejected, the effect of quantum mechanics on metaphysics can be meaningfully investigated. Quantum mechanics presents problems for philosophy, and metaphysics in particular, in the areas of the nature of reality, determinism, and causality.

5. Quantum Mechanics and the Nature of Reality

The metaphysical problem of Mind-Matter Dualism, according to which reality is external to, and independent of the observer, is at the foundation of both the classical physics of Isaac Newton and the empiricism of John Locke. For Newton and Locke, consciousness is a merely subjective epiphenomenon of an objective reality. In classical physics the mathematical model is concerned with what is observed, but in quantum mechanics, the mathematical model by itself never produces observations. Rather, the state function must be interpreted in order to relate it to experimental observations, providing only a summary of the probabilities for various measurement results. The fundamental role of measurement in quantum mechanics thereby leads to an apparent breakdown of the independence of the observer and the observed.

Although a body of exact mathematical laws exists, these laws cannot be interpreted as expressing

[12] In fact, to explain the connection between electricity and matter, some scientists in the late nineteenth century argued there had to be a fundamental unit of electricity — this unit was named “electron” by the Irish physicist, George Stoney, in 1891.

[13] Karl Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge*, p. 253.

simple relationships between objects existing in space and time. While the observable predictions of this theory can be approximately (but not uniquely) described in such terms, the wave and the particle pictures both possess the same approximate validity. This indeterminateness results directly from the inter-determinateness of the concept "observation". Which objects are to be considered as part of the observed system and which as part of the observer's apparatus can only be decided arbitrarily.[14]

6. Quantum Mechanics and Determinism

Determinism may be defined as the position that the world is governed by (or ruled by) determinism if and only if, given a specified set of initial conditions at a time t, what happens afterwards is fixed as a matter of natural law. In other words, sufficient knowledge of natural laws and initial conditions would enable future events to be predictable. This view presupposes the Newtonian space/time framework, according to which the notion of a "world-at-a-given-time" is objective and meaningful. The idea that objects move and strike each other in ways that can be predicted with only slightly-less predictable results has been shown to be false, even in Newtonian physics. Quantum mechanics has been interpreted as being consistent with the argument that some basic events may be truly random and non-deterministic.

Born wrote that while induction permits generalization from a number of observations to a general rule, there is, in fact, no definite criterion for its validity. Even though science has developed rules for its application, there is no logical argument for accepting induction. For Born, therefore, induction is a "metaphysical principle". [15] Science attempts to explain processes as being determined by particular causes and hence predictable. According to this approach, determinism is not merely synonymous with causality; there is a close relationship between determinism and probability. The indeterminacy relation is associated with quantum mechanics. but there is no "probabilistic causality". There are, however, statistical laws, the existence of which appears to be consistent with determinism.

Determinism cannot, however, be accepted congruently with Heisenberg's Uncertainty Principle. The *Principle of Determinism* posited by Pierre Simon de Laplace, states that:

> We ought to regard the present state of the universe as the effect of its anterior state and as the cause of the one which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it – an intelligence sufficiently vast to submit these data to analysis – it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past,

[14] Werner Heisenberg, *Philosophic Problems of Nuclear Science*, p. 63

[15] Max Born, *Natural Philosophy of Cause and Chance*, Oxford, 1949, p. 7., quoted in Karl Popper's *Conjectures and Refutations: The Growth of Scientific Knowledge*, p. 53.

> would be present to its eyes.[16]

However, Heisenberg's Uncertainty Principle destroys the first premise of this statement because the precise position and velocity of a particle cannot both be determined at the same time.

7. Quantum Mechanics and the Principle of Causality

Mach wrote that neither cause nor effect exists in nature[17]. He goes on to say that it can be easily demonstrated that all versions of the law of causality have a subjective basis and that there need be no correspondence with what actually occurs in nature[18]. Most German physicists, especially Planck, treated the issues of determinism and causality within a Kantian framework, and therefore acknowledged a close connection between causality and realism. Mach, however, reinterpreted causality as "functional dependence" and thereby started a tradition of indeterminism because the *a priori* categories were no longer applicable as a criterion for empirical reality. Mach rejected the "Kantian" notion of causality as a metaphysical encumbrance creating as it does insoluble metaphysical difficulties. Nevertheless, if empirical reality is analysed mathematically, then "it becomes obvious that the reference to unknown fundamental variables which are not given (things-in-themselves) is purely fictitious and superfluous."[19]

In *Determinism and Indeterminism in Modern Physics*, Cassirer pinpointed the crux of the problem as being the distinction between causality and the object of the laws. According to Cassirer, this theory was prefigured in his *Substance and Function* (especially in chapter 4), which had focussed on the dissolution of substantialism in modern philosophy[20], a tendency which Cassirer saw as providing the background for Mach's reinterpretation of causality. Cassirer maintained a strongly relativised *a priori* notion of causality:

> This knowledge [of other subjects], too, must above all be secured by a universal principle; and where shall we find such a principle if not in the principle of causality, which is the actual *a priori* for all knowledge of reality and appears to be the only bridge by which we can pass beyond the narrowly circumscribed sphere of immanence, beyond the phenomena of our own consciousness?[21]

Cassirer's position is similar to Mach's in that, for Cassirer, the principle of causality does not express

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[16] P. S. Laplace*, A Philosophical Essay on Probabilities*, p. 4.

[17] E. Mach, *Op. Cit*., p. 474.

[18] *Ibid*, p. 495.

[19] Ernst Mach, *The Analysis of Sensations*, Chapter 1, p. 11

[20] Ernst Cassirer: "I have attempted elsewhere to show at length how this "substantialistic" conception underwent a gradual change—how the concept of substance was increasingly pushed back and finally displaced by the pure concept of function. In these considerations I confined myself to the development of classical physics and its contemporary situation", from *Determinism and Indeterminism in Modern Physics* , p.130.

[21] E. Cassirer, *The Philosophy of Symbolic Forms*, p. 82

anything about the metaphysical essence of things but, rather, presents an answer to the question of how it is possible to arrive at a "determinate experiential concept" from what ever occurs.[22]

For Heisenberg, there is an apparent contradiction between the fact that our space-time form of intuition (*Anschauungsform*) and the laws of causality are not independent of all experience since they are essential constituents of every physical theory, but as Bohr in particular has stressed, the premise of every objective scientific experience is the applicability of our space-time form of intuition and of the law of causality. Nonetheless, co-ordinating a definite cause to a definite effect only makes sense when both can be observed without introducing a foreign element disturbing their interrelation. The very nature of the law of causality means that it can be defined only for isolated systems, but in atomic physics it is not possible to observe even approximately isolated systems.[23] Heisenberg held that the apparent contradiction can be resolved by taking into consideration the fact that physical theories may be structured differently from those of classical physics only when they are not concerned with the field of common experience which is the domain of classical physics. Thus, he contends, modern physics has defined the limits of the idea of the *a priori* in the exact sciences more accurately than was possible at the time of Kant.[24]

8. Quantum Mechanics and Analyticity

W. V. O. Quine has shown that sentences cannot be distinguished purely by virtue of their meaning. He has written that there are no analytic sentences, and that it is "folly to seek a boundary between synthetic statements, which hold contingently on experience, and analytic statements, which hold come what may"[25]. Quine's contention has had a dramatic effect on philosophical disciplines that rely upon there being a notion of analyticity, such as the linguistic theory of necessary truth and the analytic theory of *a priori* knowledge. The discovery of quantum mechanics has added to this effect by leading to the abandonment of the principle of excluded middle. Hilary Putnam, building on Quine's denial of the analytic-synthetic distinction, argued that, in general, the facts of propositional logic have a similar epistemological status to facts about the physical universe; what has been learned from the laws of mechanics, of general relativity, and, in particular, of quantum mechanics, provides a compelling case for abandoning certain principles of classical logic: "Logic is as empirical as geometry. … We live in a

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[22] E. Cassirer, *Determinism and Indeterminism in Modern Physics*, p. 29.

[23] W. Heisenberg, *Philosophic Problems of Nuclear Science*, pp. 62-63.

[24] *Ibid*, p. 21

[25] W. V. O. Quine, "Two Dogmas of Empiricism", in *Concepts: Core Readings*, Edited by Eric Margolis and Stephen Laurence , Chapter 5

world with a non-classical logic."[26] Therefore, if one is to be a realist about the physical phenomena as described by quantum mechanics, then one has to substitute quantum logic for classical logic, as proposed by Garrett Birkhoff and John von Neumann who argued that quantum mechanics requires a revolution in the understanding of logic *per se*.

9. Quantum Mechanics and Perception

Werner Heisenberg records an encounter in which Albert Einstein pointed out to him that the very concept of observation was itself already problematic. Every observation presupposes a known, unambiguous connection between the phenomenon to be observed and the sensation which eventually penetrates consciousness. This connection is only certain, however, if the natural laws by which it is determined are also known. In atomic physics as currently understood, however, these laws are undetermined. Thus, even the concept of 'observation' has no clear meaning; what first determines what can be observed is *theory*. Previous to the discovery of quantum mechanics, it was always possible to start with the idea of an objective world subsisting in space and time and determined by the laws of nature but now such an idealization is no longer possible. "Here the laws of nature were dealing with temporal change of the possible and the probable. But the decisions leading from the possible to the actual can be registered only in statistical fashion, and are no longer predictable."[27] Thus, Heisenberg, appears to be advocating a form of philosophical idealism whereby reality is only what can be observed. If different scientists have different observations, then there must be different realities which depend on the observer.

According to Heisenberg, progress in science has been at the expense of the making the phenomena of nature immediately and directly comprehensible.[28] This position echoes that of Cassirer who contended that only if science abandons any attempt to provide a direct copy of reality by means of the senses can it represent this reality as a necessary connection of causes and effects. By going beyond the given, science creates means for representing reality according to laws.[29] In his essay "The Concept of Group and the Theory of Perception"[30] Cassirer follows Helmholtz by stating that an acceptance of certain axioms of congruency between different parts of space is required for concrete measurement, but that these axioms imply presuppositions regarding the extent by which figures may be displaced

[26] Hilary Putnam, *Mathematics, Matter and Method*, Cambridge University Press, 1976.
[27] Werner Heisenberg, *Encounters with Einstein*, pp. 114-122.
[28] W. Heisenberg, *Philosophic Problems of Nuclear Science*, p. 39.
[29] Ernst Cassirer, *Substance and Function*, pp. 164-165.
[30] Ernst Cassirer, "The Concept of Group and the Theory of Perception", *Philosophy and Phenomenological Research*, Volume V, No. 1, September 1944.

without transformation. He posits the idea that perception appears to have some innate aspect in that the basic cluster that comprises the kinaesthetic perception of the body shares a primary affinity with some spatial representations of abstract finite groups. Cassirer goes on to say that the invariants, that is whatever remains unchanged by such motions, become in some sense critical to both perception and knowledge of space. With this idea of invariants, it is possible to make sense of the perceptual world. This abstraction from perception forms a primary foundation for knowledge, and in essence solves the epistemological riddle of the manner in which knowledge can be obtained from perception.

10. Quantum Mechanics and Physical Reality

There are two fundamental models of physical reality in physics as currently understood: relativity, a macro level of reality, and quantum mechanics, a micro level of reality. At the micro level, particles can be in two places at once (superposition of the two alternatives) and can disappear and reappear in unpredictable locations (non-locality). Particles can even act differently according to whether they are being observed or not. In 1957 Hugh Everett introduced an approach to quantum mechanics according to which there are multiple worlds in the Universe existing in parallel with the world of which we are directly aware. This theory, as further developed by B. S. De Witt, *et al.*, is called the "Many-Worlds Interpretation" (MWI)[31]. The postulation of the existence of the other worlds makes possible the removal of randomness and action at a distance from quantum mechanics — two elements of quantum mechanics which Einstein, inter alia, could not accept and which led Erwin Schrodinger, one of the founders of Quantum Theory, to say "I don't like it and I'm sorry I ever had anything to do with it"[32].

The Many Worlds Interpretation consists of a mathematical theory which yields evolution in time of the quantum state of the single universe as well as a prescription for a correspondence between the quantum state of the Universe and one's experiences. Everett proposed his relative-state formulation of quantum mechanics as a way of avoiding the problem that arises from the standard collapse (von Neumann-Dirac) formulation of quantum mechanic[33], namely, that observers always be treated as external to the system described by the theory. Everett held that:

> We shall be able to introduce into [the relative-state theory] systems which represent observers. …The behavior of these observers shall always be treated within the framework of wave mechanics. Furthermore, we shall deduce the probabilistic assertions…as subjective appearances to such observers, thus placing the

[31] H. Everett, "Relative State Formulation of quantum mechanics", *Review of Modern Physics* 29, pp. 454-462.

[32] Source: University of Utah: http://www.sci.utah.edu/~weiss/quotes/science.html

[33] J. Von Neumann described measuring devices in terms of possibility waves just like atoms, but this means that the act of measurement has a special status whereby it has the power to collapse the wave function from many parallel possibilities (the pre-measurement superposition of possibilities) to just one (the actual measurement result).

> theory in correspondence with experience. We are then led to the novel situation in which the formal theory is objectively continuous and causal, while subjectively discontinuous and probabilistic. While this point of view thus shall ultimately justify our use of the statistical assertions of the orthodox view, it enables us to do so in a logically consistent manner, allowing for the existence of other observers."[34]

D. Z. Albert and B. Loewer[35] took Everett's idea that "the formal theory [of quantum mechanics] is objectively continuous and causal, while subjectively discontinuous and probabilistic" and used it in their many-minds theory which distinguishes between the time evolution of an observer's physical state, which is continuous and causal, and the evolution of an observer's mental state, which is discontinuous and probabilistic. In order to have the observer's mental state supervene in some way on his physical state, Albert and Loewer associate with each observer a continuous infinity of minds.

Unfortunately, while Albert and Loewer's postulation of the existence of the other worlds makes possible the removal of randomness and action at a distance from quantum mechanics, it postulates a reality of myriad worlds and an infinity of minds, which is highly non-intuitive. In Everett's model, the reason why one is unable to perceive the real existence of multiple universes is accounted for by the fact that each human observer perceives only a single universe; human perception is limited to a single sector of the real world. According to standard Quantum Theory, subjective observation of certain events actually affects the objective outcome of the physical world to a certain degree. The Many Worlds Interpretation, on the other hand, postulates that all consciousness does is "choose" one of a multiple of probabilistic choices. Niels Bohr said that "Anyone who is not shocked by quantum theory has not understood it."[36] This applies even more so to the Many Worlds Interpretation.

11. Comments

The major impact of quantum mechanics on metaphysics has been: to undermine the principle of causality, the idea of strict determinism and predictability, and mind-matter dualism; and also to force a re-interpretation of reality. Quantum mechanics has not "solved" any metaphysical problem to every philosopher's satisfaction: reactions range from the assertion that it is only in the microscopic realm that the basic concepts essential for understanding the familiar everyday world fail to have any meaning, to a view that places human consciousness at the centre of the observable universe. In emphasizing the role of the observer, quantum mechanics would appear to promote an idealistic or even solipsistic position, yet its notable successes in explaining chemistry, for example, would appear

[34] H. Everett, "The Theory of the Universal Wave Function", in *The Many-Worlds Interpretation of Quantum Mechanics*, p. 9.

[35] D. Z. Albert and B. Loewer: "Interpreting the Many Worlds Interpretation", *Synthese* 77: 195-213.

[36] As quoted in *Meeting the Universe Halfway* (2007) by Karen Michelle Barad, p. 254, with a footnote citing *The Philosophical Writings of Niels Bohr* (1998).

to support a form of materialism. Quantum mechanics does undermine the realist's view that reality is two-way-independent of appearance, or that appearance does not determine reality. For Eugene Wigner, it is the consciousness of the observer that brings about the collapse of the wave function. In addition, the premise that particles are indistinguishable and under-determined invalidates Leibnitz's *Principle of the Identity of Indiscernibles*. Quantum mechanics renders direct un-mediated realism impossible, but realists could follow Cassirer's structuralist approach by developing an ontology of structure which is compatible with quantum mechanics: Cassirer concluded that particles are describable only '"as points of intersection" of certain relations' and felt that this assumption was fully confirmed[37]. For a strong idealist, quantum mechanics appears to support Berkeley's position that *esse est percipi*, while for others, it might appear to support Fichte's *Wissenschaftslehre*, in that quantum mechanics could provide the determining factor for the real.

Mind-matter dualism is undermined by quantum mechanics, especially by Bohr's non-locality principle which supports the view that everything in the world is a part of everything else. Eugene Wigner has stated that "The laws of Quantum mechanics itself cannot be formulated. . . without recourse to the concept of consciousness"[38], however, some modern dualists such as D. Z. Albert[39] and B. Loewer[40] interpret this view as supporting their contentions that minds are non-physical. On the other hand, Roger Penrose interprets quantum mechanics as supporting a different type of metaphysical dualism. Matter waves have physical reality, and could be said to conform to Kant's "things-in-themselves", whereas the act of observation which collapses the wave function conforms to Kant's act of synthesis whereby phenomenal objects are introduced into consciousness and subjected to the categories of understanding. Penrose suggests that any quantum superposition will eventually reach a specific, objective threshold for collapse (or reduction) and thus quantum superposition is actually a separation in underlying reality. Further, this objective reduction is an emergent property at a level which can be predicted using the Heisenberg Uncertainty Principle.[41] Cassirer noted, however, that, for Kant, permanence is a necessary condition for the determination of phenomena as objects[42]. Belief in such permanence was based on the Newtonian concept of an object moving independently in space and time, but quantum mechanics does not allow separation of the observer and the observed and,

[37] Ernst Cassirer, *Determinism and Indeterminism in Modern Physics*, p. 180.
[38] Eugene Wigner, "The Probability of the Existence of the Existence of a Self-Reproducing Unit", in M. Polanyi's: *The Logic of Personal Knowledge*, p. 232.
[39] D. Z. Albert, *Quantum Mechanics and Experience*, 1992.
[40] B. Loewer, "Comment on Lockwood", *British Journal for the Philosophy of Science*, 47: 229-232, 1996.
[41] Cf. Roger Penrose, *The Emperor's New Mind*, Oxford University Press, 1990
[42] Ernst Cassirer, *Philosophy of Symbolic Forms*, Volume III, p. 458.

according to the Copenhagen Interpretation of quantum mechanics, nature is non-local.

Heisenberg has noted that theories of physics differ in structure from those of classical physics only when the aims of these theories are no longer those of immediate sense perception. Only by leaving the field of common experience dominated by classical physics has modern physics been able to define more accurately the limits of the idea of the *a priori* in the exact sciences, at least more accurately than was possible at the time of Kant. He goes on to say that:

> there has not yet been a discussion, based on the new outlook, that is sufficiently thorough to show how far this idea is still fruitful in the wider philosophical fields which were essential for Kant. … These special questions of the theory of perception are already connected with the second great problem facing physical theory: that of giving information about the more general interrelations of nature, of which we, ourselves, are part.[43]

Perhaps, along with Heisenberg, we must reject the view that the example of science can lead to philosophic systems which assume "a certain truth-like the '*cogito, ergo sum'* of Descartes as the starting point from which all questions of 'Weltanschauung' could be addressed" and accept that "nature, through the medium of modern physics has reminded us very clearly that we should never hope for such a firm basis for the comprehension of the whole field of 'things perceptible'"[44]. Nevertheless, along with Einstein many continue to hope that "The most incomprehensible thing about the universe is that it is comprehensible"[45]despite all quantum mechanical evidence to the contrary. Quantum mechanics has opened many possibilities for re-interpreting reality but, in doing so, appears not so much to have undermined metaphysical speculation, but, rather, to have undermined epistemology itself. How can we specify how we know without specifying what we know, and how can we specify what we know in a probabilistic universe? If the Many Worlds Interpretation (MWI) is correct, then a new theory of consciousness is required.

12. Summary

As stated at the beginning of this paper, the discovery of quantum mechanics has significantly influenced physics and other sciences, but its impact on metaphysics has been questionable. In many cases, there occurred only a re-interpretation of already existing ideas and, for certain philosophers, quantum mechanics has been interpreted as a justification for previous positions. I would like to suggest that this may well be a reflection of the positions taken by physicists themselves, many of

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[43] Werner Heisenberg, *Philosophic Problems of Nuclear Science*, pp. 20-21.

[44] *Ibid*, p. 25.

[45]Quoted in Banesh Hoffman with Helen Dukas, *Albert Einstein, Creator and Rebel*, Viking, 1972, p. 18.

whom share Einstein's and Schrödinger's difficulty in accepting quantum mechanics as anything more than an incomplete heuristic, or as just a mathematical interpretation of reality. More work must be done in both disciplines if "quantum metaphysics" is to become a paradigm.

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