Perspective

On Some Metaphysical Problems of Many Worlds Interpretation of Quantum Mechanics

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Abstract

Despite its enormous practical success, many physicists and philosophers alike agree that the quantum theory is full of contradictions and paradoxes which are difficult to solve consistently. Even after 90 years, the experts themselves still do not all agree what to make of it. The area of disagreement centers primarily around the problem of describing observations. Formally, the so-called quantum *measurement problem* can be defined as follows: the result of a measurement is a superposition of vectors, each representing the quantity being observed as having one of its possible values. The question that has to be answered is : how this superposition can be reconciled with the fact that in practice we only observe one value. *How is the measuring instrument prodded into making up its mind which value it has observed?* Among some alternatives to resolve the above QM measurement problem, a very counterintuitive one was suggested by Hugh Everett in his 1955 Princeton dissertation, which was subsequently called the Many-Worlds Interpretation of QM (MWI). In this paper, we will not discuss all possible scenarios to solve the measurement problem, but we will only shortly discuss Everett's MWI, because it has led to heated debates on possibility of multiverses, beyond the Universe we live in. We also discuss two alternatives against MWI proposal: (a) the so-called *scale symmetry theory*, and (b) the Maxwell-Dirac isomorphism. In last section, we also discuss shortly MWI hypothesis from philosophical perspective.

Keywords: Quantum measurement problem, many-worlds interpretation, quantum metaphysics, multiverse, realism interpretation, scale symmetry, Maxwell-Dirac isomorphism.

1. Introduction

In its simplest form the quantum theory of measurement considers a world composed of just two dynamical entities, a system and an apparatus. According to the Copenhagen interpretation of QM, at the point of time when an observer operates the apparatus to observe the system, the system's wave function collapse. But the exact mechanism of wave function collapse is unknown. Furthermore, it is difficult to model the correlation between a *macroscopic* observer and apparatus (governed by classical physics) with the *microscopic* system in question, which is

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supposed to be governed the Schrödinger's wave function. This is known as quantum measurement problem, which baffled many physicists since the early years of QM development.

To quote De Witt's paper in *Physics Today* [7]:

> At this point Bohr entered the picture and deflected Heisenberg somewhat from his original program. Bohr convinced Heisenberg and most other physicists that quantum mechanics has no meaning in the absence of a classical realm capable of unambiguously recording the results of observations. The *mixture of metaphysics with physics*, which this notion entailed, led to the almost universal belief that the chief issues of interpretation are epistemological rather than ontological: The quantum realm must be viewed as a kind of ghostly world whose symbols, such as the wave function, represent potentiality rather than reality.

Apparently, Everett also realized that Copenhagen interpretation is largely incomplete. In his 1955 PhD thesis, Everett essentially proposed a resolution from measurement problem by assuming a multitude of possibilities, which is why his hypothesis is called Many Worlds Interpretation.

In De Witt's words:[7]

> … it forces us to believe in the reality of all the simultaneous worlds represented in the superposition described by equation 5, in each of which the measurement has yielded a different outcome. Nevertheless, this is precisely what EWG would have us believe. According to them the real universe is faithfully represented by a state vector similar to that in equation 5 but of vastly greater complexity. This universe is constantly splitting into a stupendous number of branches, all resulting from the measurement like interactions between its myriads of components. Moreover, every quantum transition taking place on every star, in every galaxy, in every remote comer of the universe is splitting our local world on earth into myriads of copies of itself.

In other words, Everett's hypothesis called for a different picture of reality, and obviously this requires a careful consideration of the distinction and boundary between physics theories and metaphysics. In the next section we will discuss several objections and critics to MWI.

2. Some Critics to Many Worlds Interpretation

Since publication of his dissertation, Everett's MWI has caused debates especially on philosophical problems related to his proposal. Such a proposition leads some physicists to argue that MWI actually moves the measurement problem into wild metaphysical speculation of branching universes. Barrett has reviewed earlier discussions on this topics.[6]

Despite acceptance of MWI by some theoretical physicists, and even Barrau [9] argued in favor of possible experimental vindication of MWI, there are also those who raise serious criticisms on such a wild hypothesis.

One critics came from Adrian Kent from Princeton University, from the same department where Everett obtained his PhD. In essence, Kent's objection on MWI is because:

> The relevance of frequency operators to MWI is examined; it is argued that frequency operator theorems of Hartle and Farhi-Goldstone-Gutmann do not in themselves provide a probability interpretation for quantum mechanics, and thus neither support existing MWI nor would be useful in constructing new MWI. [5]

Furthermore, he argues:

> Firstly, the very failure of MWI proponents to axiomatize their proposals seems to have left the actual complexity of realistic MWI widely unappreciated. It may thus possibly be tempting for MWI advocates to assume that there is no real problem; that Everett's detractors either have not understood the motivation for, or merely have rather weak aesthetic objections to, his program. (Hence perhaps the otherwise inexplicable claim by one commentator that "Avoiding this [prediction of multiple co-existing consciousnesses for a single observer] is their [Everett's opponents'] motivation for opposing Everett in the first place.")
>
> Secondly, MWI seem to offer the attractive prospect of using quantum theory to make cosmological predictions. The trouble here is that *if MWI is ultimately incoherent and ill-founded, it is not clear why one should pay attention to any quantum cosmological* calculations based on it. [5, p. 27]

In answering frequent question of what are the alternatives to MWI hypothesis, Kent outlined a number of ideas, including subquantum physics.

Another critics came from Steven Weinberg. For example, in 2005 interview with Dan Falk, Steven Weinberg still has objection on multiverse hypothesis. Meanwhile, he agrees that positivism or constructivism may be no longer valid in physics sciences, but he also admits that he still tries to figure out an alternative interpretation of QM:

> SW: And sometimes, as with the example of positivism, the work of professional philosophers actually stands in the way of progress. That's also the case with the approach known as constructivism — the idea that every society's scientific theories are a social construct, like its political institutions, and have to be understood as coming out of a particular cultural milieu. I don't know whether you'd call it a philosophical theory or a historical theory, but at any rate, I think that view is wrong, and I also think it could impede the work of science, because it takes away one of science's great motivations, which is to discover something that, in an absolute sense, divorced from any cultural milieu, is actually true.

> Dan Falk: You're 81. Many people would be thinking about retirement, but you're very active. What are you working on now?
>
> SW: There's something I've been working on for more than a year — maybe it's just an old man's obsession, but I'm trying to find an approach to quantum mechanics that makes more sense than existing approaches. I've just finished editing the second edition of my book, *Lectures on Quantum Mechanics*, in which I think I strengthen the argument that none of the existing interpretations of quantum mechanics are entirely satisfactory.

Weinberg himself has proposed his own theoretical physical interpretation of QM, albeit his theory is non-ontological in nature. He wrote:[14]

> ψ is theoretically physical and describes the probabilistic possibilities, as the Copenhagen interpretation implies. It has physical units (see Eq. (3)). ψ is also, naively, a function of a real spacetime coordinate argument solving a partial differential equation, such as the time-dependent Schrödinger equation, for example, with spacetime partial derivatives. All this argues for theoretically physical formalism (*not ontology*), applicable predictably prior to 'Copenhagen observation.'

Therefore, in the same spirit with Weinberg's reserved position against MWI hypothesis, in the following section we will discuss two simpler alternatives which seem quite worthy for further considerations: (a) scale symmetry theory, (b) a more realistic interpretation of quantum wave function based on Maxwell-Dirac isomorphism.

3. Resolution to the problem based on scale symmetry theory

In a semi-popular article in *Quanta Magazine*[10], Wolchover describes how some theoretical physicists who feel unhappy with multiverse metaphysical problem, have come up with new theories where mass and length are no longer fundamental entities. In a scale-symmetry theory, advocated earlier by Bardeen around 1995, the origin of mass can be derived without invoking Higgs mechanism.[11]

Proponents of scale symmetry theory argue that this approach has clear prospect to prove that multiverse hypothesis (MWI) is an *excess baggage*. In essence, they believe that the key to the correct answer to the measurement problem is not by pondering metaphysical problems such as the existence of multiple realities and multiple histories, but by examining our assumptions on mass, length, and scales. See also Hashino et al. [12].

Resolution to the problem based on realistic Maxwell-Dirac isomorphism

Actually, there is a simpler resolution to the aforementioned QM measurement problem, although it is not quite popular yet, i.e. by admitting that (a) Schrodinger's wave function is unphysical therefore it has no value for realistic physical systems, (b) because of such an unrealistic wave function, the measurement problem is caused by confusion on the physical meaning of quantum wave function, (c) it is required to reconcile physical wave function obtained from QM and from classical electrodynamics theory.

Once we accept these, then we should find out the correct physical meaning of wave function, by formal connection between QM and classical electrodynamics. In other words, contradictions and confusions can be removed once we reconcile quantum picture with classical electrodynamics picture of wave function, instead of crafting unfounded assumption of many-worlds which only creates metaphysical excess baggage.

There are some papers in literature which concerned with the formal connection between classical electrodynamics and wave mechanics, especially there are some existing proofs on Maxwell-Dirac isomorphism. Here the author will review two derivations of Maxwell-Dirac isomorphism i.e. by Hans Sallhofer and Volodimir Simulik. In the last section we will also discuss a third option, i.e. by exploring Maxwell-Dirac isomorphism through quaternionic language.

a. Sallhofer's method

Summing up from one of Sallhofer's papers[1], he says that under the sufficiently general assumption of periodic time dependence the following connection exists between source-free electrodynamics and wave mechanics:

$$\sigma \cdot \begin{bmatrix} rotE + \dfrac{\mu}{c}\dfrac{\partial}{\partial t}H = 0 \\ rotH - \dfrac{\varepsilon}{c}\dfrac{\partial}{\partial t}H = 0 \\ div\varepsilon E = 0 \\ div\mu H = 0 \end{bmatrix}_{divE=0} \equiv \left[(\gamma \cdot \nabla + \gamma^{(4)}\partial_4)\Psi = 0\right] \tag{1}$$

In words: Multiplication of source-free electrodynamics by the Pauli-vector yields wave mechanics.[1]

In simple terms, this result can be written as follows:

$$P \cdot M = D, \tag{2}$$

Where:

P = Pauli vector,

M = Maxwell equations,

D = Dirac equations.

We can also say: *Wave mechanics is a solution-transform of electrodynamics.* Here one has to bear in mind that the well-known circulatory structure of the wave functions, manifest in Dirac's hydrogen solution, is not introduced just by the Pauli-vector.[1]

b. Simulik's method

Simulik described another derivation of Maxwell-Dirac isomorphism. In one of his papers[2], he wrote a theorem suggesting that the Maxwell equations of source-free electrodynamics which can be written as follows:

$$\begin{aligned} rotE + \frac{\mu}{c}\frac{\partial}{\partial t}H = 0 \\ rotH - \frac{\varepsilon}{c}\frac{\partial}{\partial t}H = 0 \\ divE = 0 \\ divH = 0 \end{aligned} \tag{3}$$

Are equivalent to the Dirac-like equation [2]:

$$\left[\gamma.\nabla - \begin{pmatrix} \varepsilon 1 & 0 \\ 0 & \mu 1 \end{pmatrix} \frac{1}{c}\frac{\partial}{\partial t}\right]\Psi^{c1} = 1, \tag{4}$$

Where in the usual representation

$$\gamma = \begin{pmatrix} 0 & \sigma \\ \sigma & 0 \end{pmatrix}, \tag{5}$$

And σ are the well-known Pauli matrices.

c. Maxwell-Dirac isomorphism through Quaternionic language

Recognizing that the Maxwell's equations were originally formulated in terms of quaternionic language, some authors investigate formal correspondence between Maxwell and Dirac equations. To name a few who worked on this problem: Kravchenko and Arbab. These authors have arrived to a similar conclusion, although with a different procedures based on Gersten decomposition of Dirac equation.[4]

It seems that the above arguments of Maxwell-Dirac isomorphism can be an alternative to the problematic MWI hypothesis. This MD isomorphism can also be extended further to classical description of boson mass which was usually called Higgs boson[3], so it may offer a simpler route to describe the origin of mass compared to scale symmetry theory.

4. Philosophical viewpoint

In our opinion, the essence of problem with MWI is captured in De Witt's remark as quoted above: "The *mixture of metaphysics with physics*." Formally speaking, Everett's many worlds interpretation of QM can be viewed as large scale implication if one accepts Feynman's *sum over history* interpretation of QM. But, it is known that Feynman famously declared that nobody understood completely Quantum Mechanics. Therefore, one should be very careful before generalize his sum over history interpretation of QM toward Universe.

Nonetheless, Everett's Multiverse found numerous followers, especially science fiction fans all over the world. And some people also relates his Multiverse as a realization of one of Borges's story: "*Garden of the forking paths*."

While we shall admit that such a Multiverse hypothesis is a nice material for science fiction novels or movies, now is the right time to ask: *Is it possible that God created Multiverse?*

Such a philosophical implication of cosmology development has been emphasized by Bernard Carr:

> By emphasizing the scientific legitimacy of anthropic and multiverse reasoning, I do not intend to deny the relevance of these issues to the science– religion debate [32]. The existence of a multiverse would have obvious religious implications [33], so contributions from theologians are important. More generally, cosmology addresses fundamental questions about the origin of matter and mind, which are clearly relevant to religion, so theologians need to be aware of the answers it provides.

Rodney identifies several problems related to multiverse hypothesis:[17]

> Among the problems identified with the hypothesis are:
>
> (1) the existence of infinitely many universes depends critically on parameter choice;
> (2) the probability that any universe in an ensemble is fine-tuned for life is zero;
> (3) the physical realization of any ensemble will exclude an infinity of possibilities;
> (4) the hypothesis is untestable and unscientific; and
> (5) the hypothesis is not consistent with the amount of order found in this universe, nor with the persistence of order.

> If these factors are taken into consideration the conclusion of the last chapter will be much stronger, because the prior probability of many universes will be further reduced and because the 'likelihood' entering Bayes's theorem will also be reduced."

It seems worth noting here to quote George Ellis's remark in his Emmanuel College lecture:[19]

> The very nature of the scientific enterprise is at stake in the multiverse debate: the multiverse proponents are proposing weakening the nature of scientific proof in order to claim that multiverses provide a scientific explanation. This is a dangerous tactic.
>
> …
>
> The often claimed existence of physically existing infinities (of universes, and of spatial sections in each universe) in the multiverse context (e.g.Vilenkin: Many Worlds in One: The Search for Other Universes) is dubious.
>
> …
>
> Here one must distinguish between explanation and prediction. Successful scientific theories make predictions, which can then be tested. The multiverse theory can't make any predictions because it can explain anything at all.

Finally, Ellis warned his fellow cosmologists:[18]

> I suggest that cosmologists should be very careful not make methodological proposals that erode the essential nature of science in their enthusiasm to support specific theories as being scientific, for if they do so, there will very likely be unintended consequences in other areas where the boundaries of science are in dispute. It is dangerous to weaken the grounds of scientific proof in order to include multiverses under the mantle of 'tested science' for there are many other theories standing in the wings that would also like to claim that mantle.
>
> *It is a retrograde step towards the claim that we can establish the nature of the universe by pure thought*, and don't then have to confirm our theories by observational or experimental tests: it abandons the key principle that has led to the extraordinary success of science.
>
> In fact we can't establish definitively either the existence or the nature of expanding universe domains that are out of sight and indeed out of causal contact with us.

5. Conclusion

Despite its enormous practical success, many physicists and philosophers alike agree that the quantum theory is full of contradictions and paradoxes which are difficult to solve consistently. Even after 90 years, the experts themselves still do not all agree what to make of it. In this paper, we review QM measurement problem which paved a way to Many-Worlds Interpretation of QM. Nonetheless, it is clear that Everett's hypothesis called for a different picture of reality, and obviously this requires a very careful consideration of the distinction between physics theories and metaphysics.

In the meantime, the problem of the formal connection between electrodynamics and wave mechanics has attracted the attention of a number of authors, especially there are some existing proofs on Maxwell-Dirac isomorphism. Here the authors review three derivations of Maxwell-Dirac isomorphism i.e. by Hans Sallhofer and Volodimir Simulik and also quaternion language.

In our opinion the above arguments of Maxwell-Dirac isomorphism can be a *simpler* alternative compared to the metaphysically problematic MWI hypothesis. (Allow us to recall Ockham's razor: the simpler explanation is more likely to be the correct answer.) This MD isomorphism can also be extended further to classical description of boson mass which was usually called Higgs boson [3], so it may be a simpler option compared to scale symmetry theory.

It is our hope that discussions presented in this paper have made clear that the entire Many Worlds Interpretation of QM is not required, once we begin to ask what is the physical meaning of wave function, instead of accepted blindly the macroscale implication of path integral interpretation of QM.

This paper was inspired by an old question: *Is there a consistent and realistic description of wave function, both classically and quantum mechanically?*

It can be expected that the above discussions will shed some lights on that old problem especially in the context of physical meaning of quantum wave function. This is reserved for further investigations.

To conclude this paper, allow us to repeat Ellis's warning to his over-enthusiastic fellow cosmologists:

> I suggest that cosmologists should be very careful not make methodological proposals that erode the essential nature of science in their enthusiasm to support specific theories as being scientific, for if they do so, there will very likely be unintended consequences in other areas where the boundaries of science are in dispute. It is dangerous to weaken the grounds of scientific proof in order to include multiverses under the mantle of 'tested science'

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