Time Division Multiverse:
A New Picture of Quantum Reality

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Abstract

In my book *Meaning of the Wave Function*, I proposed a new interpretation of the wave function in term of random discontinuous motion (RDM) of particles in three-dimensional space. In this paper, I argue that this interpretation of the wave function also solves the measurement problem. The resulting picture is time division multiverse, in which worlds exist fundamentally in a time devision way in three-dimensional space, and the Born rule can be directly derived from the RDM of particles.

> *Time-division multiplexing (TDM) is a method of putting multiple data streams in a single signal by separating the signal into many segments, each having a very short duration.* — A definition from TechTarget[1]

There are two fundamental problems in the conceptual foundations of quantum mechanics. The first one is the physical meaning of the wave function, and the second one is the measurement problem. Only after solving these two problems, can we understand quantum mechanics and know what it says about the nature of reality. In my book *Meaning of the Wave Function* (Gao, 2017), I proposed an interpretation of the wave function in term of random discontinuous motion (RDM) of particles in three-dimensional space. In this note, I will argue that this new interpretation of the wave function also solves the measurement problem. The resulting picture will be time division multiverse, in which worlds exist fundamentally in a time

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[1] https://whatis.techtarget.com/definition/time-division-multiplexing-TDM

devision way in three-dimensional space, and the Born rule can be derived directly from the RDM of particles.

Consider a typical z-spin measurement, in which an observer M measures the z-spin of a spin one-half system S that is in a superposition of two different z-spins. By the linear Schrödinger evolution, the state of the composite system after the measurement will be the superposition of M resulting z-spin up and S being z-spin up and M resulting z-spin down and S being z-spin down:

$$\alpha \left|up\right\rangle_S \left|up\right\rangle_M + \beta \left|down\right\rangle_S \left|down\right\rangle_M , \tag{1}$$

where α and β are nonzero and satisfy the normalization condition $|\alpha|^2 + |\beta|^2 = 1$.

According to the interpretation of the wave function in term of RDM of particles (Gao, 2017), a quantum system is composed of particles with mass and charge which undergo random discontinuous motion (RDM) in three-dimensional space, and the wave function represents the propensities of these particles which determine their random discontinuous motion, and as a result, the state of motion of particles is also described by the wave function.[2] At each instant all particles have a definite position, while during an infinitesimal time interval around each instant they move throughout the whole space where the wave function is nonzero in a random and discontinuous way, and the probability density that they appear in every possible group of positions in space is given by the modulus squared of the wave function there. Visually speaking, the RDM of each particle will form a mass and charge cloud in space (during an infinitesimal time interval around each instant), and the RDM of many particles being in an entangled state will form many entangled mass and charge clouds in space. Note that the clouds corresponding to different branches of an entangled superposition exist not at the same time but in different sets of instants or different time subflows. This is important for the following analysis.

In the above experiment, there are only one system and one observer at each instant. The positions of the particles representing the measurement result of the observer are definite at each instant. Moreover, these particles randomly jump between the two result branches $\left|up\right\rangle_M$ and $\left|down\right\rangle_M$ over time, and the probability of they being in these two branches at each instant are $|\alpha|^2$ and $|\beta|^2$, respectively. Then at each instant there is an observer who obtains a definite result corresponding to one of the two result branches in the post-measurement superposition. Moreover, which result she obtains is randomly determined at the instant, and the probability of she obtaining

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[2] Note that there is also a picture of random discontinuous motion of particles in Bell's Everett (?) theory or Bohm's theory without trajectories (Bell, 1981). In that theory, however, the wave function is regarded as a real physical field in configuration space, and the particles arguably have no mass and charge as in Bohm's theory.

a particular result is equal to the modulus squared of the wave function associated with the result, namely the probability of she obtaining the result z-spin up is $|\alpha|^2$ and the probability of she obtaining the result z-spin down is $|\beta|^2$. This provides a direct derivation of the Born rule.

Now the crucial question is: are the observers who obtain different results in the two result branches the same observer? or more generally, do the two result branches of the post-measurement superposition represent the same world? The answer is arguably no. First, the two result branches of the post-measurement superposition (as two groups of clouds in space) do not exist at the same time during a time interval; rather, they exist in different sets of instants or different time subflows. This means that for each result branch, the other result branch does not exist in space and time. Next, the two result branches have no interactions with each other. The system and the observer in one result branch do not interact with the system and the observer in the other result branch. Lastly, the systems and the observers in different result branches have different interactions with each other and their environment. In particular, the observers in the two result branches have different memories. Thus, it is arguable that the two result branches of the post-measurement superposition represent two parallel worlds in space and time, in each of which there is an observer who obtains a definite, random result with the Born probability.

Here a world is defined (as usual) as the total of all entities which exist in the same space and time and interact with each other. Entities in different worlds exist in different time subflows and they do not interact with each other; for entities in one world, the entities in other worlds do not exist in space and time. Note that such worlds are not Everett's (1957) relative states or Wallace's (2012) emergent macroscopic multiplicity at the level of structure. They exist at the fundamental level and originate directly from the underlying ontology of quantum mechanics. Concretely speaking, these worlds originate from the RDM of particles and the laws of motion; we have the same particles, but they can form a time division multiverse by means of their random discontinuous motion.[3]

Certainly, decoherence will help generate stable, quasi-classical worlds as usual, although they are not necessary for the existence of the worlds defined above. In addition, observers and their interactions with the environment

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[3] Note that this analysis is different from Bell's Everett (?) theory (Bell, 1981). The latter is plagued by an empirical incoherence problem due to the unreliability of an observer's memories of measurement results (Barrett, 1999), and is arguably inconsistent with quantum mechanics and experiments either (Gao, 2021a). By comparison, the above many-worlds theory of RDM of particles agrees with quantum mechanics and experiments, and an observer's memories of measurement results are also reliable in each world in the theory. Note also that the RDM of particles is not part of the laws of motion but the ontology itself, and its existence is supported by an analysis of quantum mechanics (Gao, 2020). Moreover, the observed thermodynamic arrow of time in our universe may already provide strong evidence for the existence of many worlds (Gao, 2021b).

will also select the actual preferred basis or which world they will live in (see Vaidman, 2021). Observers with quite distinct brain structures may perceive different worlds (Penrose, 2004).

A final point. If the wave function indeed represents the RDM of particles in three-dimensional space, then no additional ontologies and postulates are introduced in the above version of the many-worlds interpretation of quantum mechanics (MWI).

To sum up, I have argued that my proposed interpretation of the wave function in term of random discontinuous motion (RDM) of particles may also solve the measurement problem. By a usual definition of worlds, the picture of quantum reality will be time division multiverse, in which worlds exist fundamentally in a time devision way in three-dimensional space. This provides a more direct solution to the two thorny problems of MWI, namely the problems of ontology and probability. Maybe the opponents of MWI such as Maudlin (2014) will be also satisfied with this new version of the theory.

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