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Interpreting Quantum Mechanics in Absolute Inductive Particular Motion

Poonam Rani[1]* Dr. Vipin Kumar[2]

[1] PhD Scholar, OPJS University, Churu, Rajasthan

[2] Associate Professor, OPJS University, Churu, Rajasthan

Abstract – This work is an attempt to recreate Quantum Mechanics conceptual foundations. First, we claim that the wave function in quantum mechanics is a definition of random discontinuous particle motion, and that the wave function's modulus square gives the particle probability density at some space locations. First, we demonstrate that the linear, non-relativistic evolution of an isolated system's wave function obeys the free Schr¨odinger equation due to the spacetime translation invariance and relativistic invariance requirements. Thirdly, we argue that the discontinuous random motion of the particles will lead to a stochastic, nonlinear collapse of the wave function. A discrete model of the energy-conserved collapse of the wave function is proposed and demonstrated to be consistent with current experiments and our macroscopic experience. We also offer a crucial review of the de Broglie-Bohm theory, the explanation of several worlds and other theories of dynamic collapse, and briefly discuss the question of the incompatibility between quantum mechanics and particular relativity.

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INTRODUCTION

Quantum mechanics is a non-relativistic theory about the wave function and its evolution according to its Schr¨odinger image. The philosophical foundations of quantum mechanics pose two big issues. The first relates to the theory of the physical meaning of the wave function. It has been commonly argued that the definition of probability is not entirely sufficient because of resorting to the ambiguous principle of estimation-although it is nowadays still the main definition in textbooks. At the other hand, the importance of the wave function is still in question in the alternatives to quantum mechanics such as the theory of de Broglie-Bohm and the definition of many worlds (de Broglie 1928; Bohm 1952; Everett 1957; De Witt and Graham 1973). Exactly what then defines the wave function? The second issue relates to wave function evolution. This has two pieces of it. One part relates to the evolution of the linear Schr¨odinger. How does the Schr¨odinger equation satisfy the linear, non-relativistic evolution of the wave function? It seems the equation still lacks a satisfactory derivation (cf. Nelson 1966). The other aspect refers to the failure of the wave function during a measurement which is generally called the problem of measurement. In quantum mechanics the postulate of collapse is ad hoc, and the theory does not inform us how a definite measurement result emerges (Bell 1990). While the alternatives to quantum mechanics already offer their respective solutions to this question, which solution is correct or in the right direction has been a hot topic of debate. Ultimately it is still unclear whether or not the collapse of the wavefunction is true. Even if the wave function collapses in certain conditions, the exact why and how the wave function collapses remains unknown. The problem of measurement was generally known as one of the most complicated and important problems in the foundations of quantum mechanics (see, e.g., Wheeler and Zurek 1983). We will seek to solve certain problems from a new perspective in this study. The aim is to understand that the problem of interpreting the wave function can be solved independently of how to solve the problem of measurement, and the solution to the first problem will then have major consequences for the second solution. While the sense of the wave function should be listed as the quantum mechanics' first interpretative problem, it has been treated as a marginal problem, particularly when compared with the measurement problem. As noted above, there are already several alternatives to quantum mechanics which provide the measurement problem with respective solutions. At their present point, however, these theories are unsatisfactory in at least one aspect; they have failed to make sense of the wave function. Different from them, our approach is to first figure out what physical state the wave function represents and then explore the answer's implications for the solutions to other basic quantum mechanics problems. It seems very important to know exactly what the wave function is if we try to find out how it progresses, e.g. whether it breaks during a calculation, or not. Such issues, however, are usually related to one another. In fact, to know what physical state a quantum system's wave function represents, we need to measure the system in the first place, while the measuring method and the outcome of the measurement are actually determined by the evolution rule for the wave function. Fortunately, it has been realized that the conventional measurement which leads to the apparent collapse of the wave function is only one form of quantum measurement, and that there is also another type of measurement which prevents the collapse of the wave function, namely the protective measurement (Aharonov and Vaidman 1993; Aharonov, Anandan and Vaidman 1993; Aharonov, Anandan and Vaidman 1996). Protective measurement is a method for measuring the expectation values of observables on a single quantum system without substantially disrupting its state, and its mechanism is independent of the controversial wavefunction collapse process and relies solely on the linear Schr¨odinger evolution and the Born law, two known parts of quantum mechanics. As a result, protective measurement can not only calculate the physical state of a quantum system and help expose the meaning of the wave function, but can also be used before experiments provide the final judgment to test the solutions to the measurement question. A complete exposition of these ideas will be given in the chapters that follow. The studies' strategy is as follows. In Chapter 2, we explore the physical meaning of wave motion for the first time. The mass and charge distributions of a quantum system as a part of its physical state can be determined as expectation values of other observables according to protective measurement. It turns out that a quantum system's mass and charge are distributed across space, and the mass and charge density at each location is proportional to the square modulus of the system's wave function there. The key to unveiling the significance of the wave function is to locate the origin of the distributions of mass and charge. The density is seen not to be actual but to be effective; it is created by the time-average of the ergodic motion of a localized particle with the total mass and the device charge. It is further argued that the ergodic movement is not constant, but discontinuous and spontaneous. Based on this finding, we say that the wave function represents the state of random discontinuous particle motion, and in particular, the modulus square of the wave function (in position space) gives the probability density of the particles occurring at certain space positions. It is shown that due to the requirements of spacetime translation invariance and relativistic invariance the linear non-relativistic evolution of the wave function of an isolated system obeys the free Schr¨odinger equation. While those specifications are already well known, the literature still lacks an explicit and complete derivation of the free Schr¨odinger equation using them. The new integrated analysis, along with the proposed wave function definition, may be helpful in understanding the physical roots of the Schr¨odinger equation. In addition, we are also discussing the physical basis and importance of the energy and momentum conservation theory in quantum mechanics. In Chapter 4, for the solutions to the measurement question, we explore the consequences of protective measurement and the suggested definition of wave function based upon it. First of all, we argue that the two no-collapse quantum theories, namely the de Broglie-Bohm theory and the definition of many worlds, are incompatible with protective measurement and the image of spontaneous discontinuous particle motion. This finding clearly implies that collapse of the wavefunction is a physical phenomenon in itself. Second, we argue that random discontinuous particle motion can provide a suitable random source for collapse of the wave function. The main point is to understand that the instantaneous state of a particle not only includes its wave function but also includes its random position, momentum and energy that undergoes the discontinuous motion, and these random variables may have a stochastic effect on the evolution of the wave function and thus contribute to the collapse of the wave function. Third, we are proposing a separate model of collapse of the energy-conserved wavefunction. The model is shown to comply with current experiments and our macroscopic experience. Finally, we also have some important feedback on other models of dynamic collapse, including the collapse-induced Penrose model and the CSL (Continuous Spontaneous Localization) model. Throughout the last chapter, we briefly discuss the incompatibility issue between quantum mechanics and special relativity throughout terms of random discontinuous particle motion. It is argued that a consistent description of random discontinuous particle motion requires absolute simultaneity, and this leads to the existence of a preferred Lorentz frame when combined with the constancy of light speed requirement. However, it is shown that the dynamics of collapse can provide a method for detecting the frame according to the model of collapse which is conserved in energy.

MEANING OF WAVE FUNCTION

A important interpretative question in quantum mechanics is the physical sense of the wave function. Despite the theory's developments of more than eighty years, however, it is still a debated subject. In addition to the traditional definition of the probability in textbooks, the alternatives to quantum mechanics often include numerous contradictory views about the wave function. Within this chapter, through a new study of the protective calculation and the mass and charge density of a quantum system, we will attempt to solve this fundamental interpretive problem. In the form of traditional impulse measurements, the importance of the wave function is often evaluated, for which the coupling interaction between the measured mechanism and the measuring device is of short duration and solid. As a consequence, while a quantum system's wave function is usually distributed over space, an impulse position measurement would eventually collapse the wave function, and can only detect the system in a random space position. Therefore it is unsurprising that the traditional definition of probability is believed to link the wave function to the likelihood of such random measurement effects.

Nevertheless, it has been recognized that there is another form of measurement that can prevent the wave function from collapsing, namely the protective measurement (Aharonov and Vaidman 1993; Aharonov, Anandan and Vaidman 1993; Aharonov, Anandan and Vaidman 1996). Protective measurement often uses a common measuring technique, but with a low and long-lasting coupling interaction and a special method to avoid collapse of the measured wave function. The general approach is to allow the measured system to be in a non-degenerate property of the entire Hamiltonian using an acceptable protective relationship (in certain cases the security is given by the measured system itself), and then to make the measurement adiabatically so that the state of the system does not change or become appreciably entangled with the measuring instrument. Such protective measurements can thus measure the expectations of observables on a single quantum system, and in particular, the mass and charging density of a quantum system as a part of its physical state, as well as its wave function, can be measured as expectations of certain observables.

The mass and charge of a quantum system are distributed throughout space according to protective measurement, and the mass and charge density in each position is proportional to the modulus square of the system's wave function there. The key to revealing the meaning of the wave function is to find the physical origin of the distributions of mass and charge. Historically, Schr¨odinger originally proposed the charging density definition for electrons when he introduced the wave function and established wave mechanics (Schr¨odinger 1926). Although the presence of an electron's charge density may provide a classical explanation for certain radiation phenomena, its explanatory capacity is very minimal. In addition, Schr¨odinger explicitly understood that the density of charge cannot be classical because his equation does not contain the normal classical density interaction.

This initial interpretation of the wave function was soon rejected and replaced by Born's probability interpretation (Born 1926), presumably since people thought that the charge density could not be measured and also lacked a consistent physical picture. Now defensive calculation re endows an electron's charging distribution with fact with a more compelling argument. The problem then is whether a clear physical explanation can be found1. To some extent our following analysis can be seen as a further development of the idea of Schr¨odinger. The irony is: that the charge distribution is not classic does not mean its non-existence; instead, its presence points to a non-classical representation of quantum reality hidden behind the function of the mathematical wave.

ANALYSIS

Protective Measurements

Protective measurements are improved methods based on weak measurements, and they can measure the expectations of observables on a single quantum system. As we have seen above, although a weak measurement does not significantly change the measured state, the measuring device's pointer also hardly moves. The change of the pointer due to the calculation is, in fact, much smaller than its uncertainty of location, and therefore little information can be gained from individual measurements. Increasing the coupling time between the measured system and the measuring tool is a potential way to mitigate the vulnerability of inadequate measures. If the state during the calculation is nearly constant, the cumulative pointer change, which is proportional to the length of the interaction, would be high enough to be known. Under normal circumstances, however, the state of the system during the calculation is not constant, and the weak coupling often contributes to a small rate of state change. As a result, the reading of the measuring device would lead to some time average based on the nature of the state determined by the measuring process, not the state that the system had prior to the measurement.

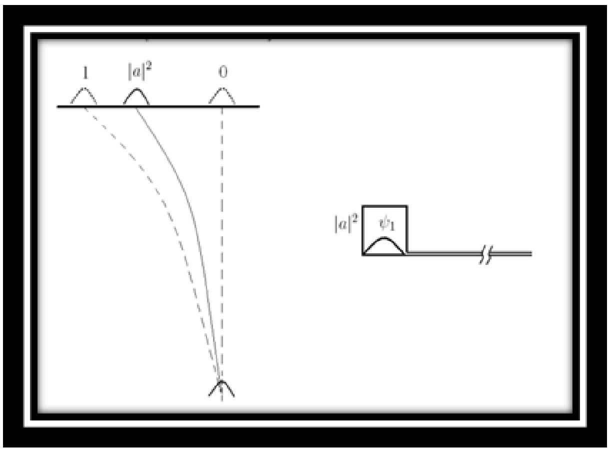

Fig.1 Scheme of a protective measurement of the charge density of a quantum system

Single particle Picture

In the case of a particle's random discontinuous motion, the particle appears to be in any possible position at a given instant, and the probability density of the particle being in each x position at a given instant t is determined by the squared module of its wave function, namely π(x, t)=, t) 2 The physical description of particle motion is as follows. The particle randomly remains in a position at a discrete moment, and at the next instant it will either remain there or appear randomly in another spot, which is presumably not in the neighborhood of the preceding spot. In this way, the particle can travel discontinuously across the entire space over a time interval that is much greater than the length of one moment, with the position probability density p(x, t). This jumping mechanism is clearly non-local, because the distance between the positions occupied by the particle at two adjacent instants can be very high. The non-local jumping mechanism is the same in any inertial frame, in the non-relativistic domain where time is absolute. But in the relativistic context, thanks to the Lorentz transformation, the jumping process can look different in different inertial frames. Let's come up with a clear review. Suppose a particle is at instant t1 in position x1 and at instant t2 in an inertial frame S in position x2. The Lorentz transformation leads to: In another inertial frame S 0 with velocity v relative to S.

$$t_1' = \frac{t_1 - x_1 v/c^2}{\sqrt{1 - v^2/c^2}},$$

$$t_2' = \frac{t_2 - x_2 v/c^2}{\sqrt{1 - v^2/c^2}},$$

$$x_1' = \frac{x_1 - vt_1}{\sqrt{1 - v^2/c^2}},$$

$$x_2' = \frac{x_2 - vt_2}{\sqrt{1 - v^2/c^2}}.$$

Since the particle's jumping process is non-local, the two events (t1, x1) and (t2, x2) can meet the spatial separation condition readily? $|x_2 - x_1| > c|t_2 - t_1|.$ Then we can always choose a possible velocity v < c which results in $t_2' = t_1'$:

$$v = \frac{t_2 - t_1}{x_2 - x_1} c^2.$$

On the absoluteness of simultaneity

The above analysis clearly demonstrates the apparent conflict between the random discontinuous motion of particles and the Lorentz transformation in special relativity. The crux of the matter lies in the relativity of simultaneity. If simultaneity is relative as manifested by the Lorentz transformation, then the picture of random discontinuous motion of particles will be seriously distorted except in one preferred frame, though the distortion is unobservable in principle. Only when simultaneity is absolute, can the picture of random discontinuous motion of particles be kept perfect in every inertial frame. In the following, we will show that absolute simultaneity is not only possible, but also necessitated by the existence of random discontinuous motion of particles and its collapse evolution. Although the relativity of simultaneity has been often regarded as one of the essential concepts of special relativity, it is not necessitated by experimental facts but a result of the choice of standard synchrony (see, e.g. Reichenbach 1958; Gr¨unbaum 1973)8 . As Einstein (1905) already pointed out in his first paper on special relativity, whether or not two spatially separated events are simultaneous depends on the adoption of a convention in the framework of special relativity. In particular, the choice of standard synchrony, which is based on the constancy of one-way speed of light and results in the relativity of simultaneity, is only a convenient convention. Strictly speaking, the speed constant c in special relativity is two-way speed, not one-way speed, and as a result, the general spacetime transformation required by the constancy of two-way speed of light is not the Lorentz transformation but the EdwardsWinnie transformation (Edwards 1963; Winnie 1970):

$$x' = \eta(x - vt),$$

$$t' = \eta[1 + \beta(k + k')]t + \eta[\beta(k^2 - 1) + k - k']x/c,$$

$$k' = \beta(k^2 - 1) + k = -\beta.$$

$$\beta(k^2 - 1) + k - k' = 0.$$

$$x' = \frac{1}{\sqrt{1 - v^2/c^2}} \cdot (x - vt),$$

$$t' = \sqrt{1 - v^2/c^2} \cdot t.$$

The above study shows the probability of preserving absolute simultaneity within the context of special relativity. One can adopt the standard synchrony which leads to simultaneity relativity, and one can also adopt the non-standard synchrony which restores simultaneity absolute. This is allowed because in special relativity there is no causal connection between two spatially separated events. However, if there is a causal influence that links two distinct events, then there will be a non-conventional basis for claiming that they are not simultaneous (Reichenbach 1958; Gr¨unbaum 1973; Janis 2010). Especially if there is an arbitrarily fast causal influence connecting two separate events in space, then these two events will be simultaneous. We'll see in the following that random discontinuous motion and its collapse evolution merely provide a non-conventional basis for the absolute simultaneity. Consider a particle being in a superposition of two spatial branches well separated. According to the random discontinuous motion picture the particle jumps randomly and discontinuously between these two branches. The particle is in one branch at an instant, and could be in the other spatially-separated branch at the next moment. The particle's disappearance in the first branch can be considered one event, and the particle's appearance in the second branch can be considered another. Clearly between these two spatially separated events there is an immediate causal connection; if the particle did not vanish in the first branch, it might not appear in the second branch. Those two things would also be considered simultaneous. Note that this inference is meaningless for observability of the two events and their causal relation. In addition, the conclusion is also irrelevant for the frame of reference, which means that simultaneity is absolute

COCNLUSION

Within this paper , we focused on two basic problems in the conceptual foundations of quantum mechanics. The first is wave function perception and the second is the question of measurement. We have concluded that protective measures can help to establish the physical nature of the action of the waves. Since the beginning of quantum mechanics the definition of wave function has been a debated question. We conclude by discussing two possible future research projects that our findings indicate and their potential consequences for future study. Under that context, I would treat a definitive decision as equal to a complete surrender. Since we can't really stop our thought in terms of space and time, and what we can't comprehend inside it, we can't comprehend at all. "Now the suggested image of random discontinuous particle motion in space and time might provide a potential explanation of what's going on in an atom and help us understand the mysterious quantum universe.

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Corresponding Author

Poonam Rani*

PhD Scholar, OPJS University, Churu, Rajasthan