Interpretation of Quantum Mechanics in Terms of Discrete Time III

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This paper approaches several fundamental problems in standard quantum mechanics, such as wave-particle duality and the measurement problem, through a new perspective of non-local waves [2]. I argue that these issues stem primarily from incomplete assumptions about physical reality in standard quantum mechanics and an exaggerated understanding of the superposition principle. Therefore, I am trying to solve the problems by extending quantum mechanics by newly establishing these concepts.

1 Introduction

Current quantum mechanics, despite its great success, has many problems in its understanding — wave-particle duality, measurement problems and the relationship between measurement and interaction, etc. One might consider these issues unimportant. But a theory lacking precise understanding naturally becomes harder to advance and should not be overlooked. Moreover, misunderstandings can hinder progress altogether.

In this paper, I will argue that many problems in current quantum mechanics are largely caused by two things: ontological assumptions about reality and an exaggerated understanding of the superposition principle. By addressing these, the paper aims to resolve inherent contradictions and show that the problems themselves may not persist under a new framework.

2 Assumptions about quantum mechanical reality

Wikipedia defines the quantum concept as follows: A quantum is the minimum amount of any physical entity (physical property) involved in an interaction.

This definition is quite appropriate. However, in this definition, the existing standard quantum mechanics seems to focus mainly on the meaning of "minimum amount of physical property". The truly important point that should not be overlooked in the definition of quantum is the part "involved in an interaction". If we pay attention to this point, we can naturally raise the following questions: If physical properties during interaction can only be measured in quantum, what is the physical reality before interaction? Since we cannot know the nature of matter except through interaction, we can only infer the reality of matter before interaction. But how is that inference being made now?

For light, the energy is quantized when interacting and exists in a local area, so its reality is inferred to be a lump like particle. However, since they also have a phase, the reality of photons is not clear. What is certain is that standard quantum mechanics defines the reality of photons by the characteristics that appear when they interact. Although this has some validity, it is still just a hypothesis, and reality may be different.

There is no way to know the reality of matter before observation. It is a kind of ontological assumption. However, no physical theory can proceed without assuming such a concept. Therefore, it is very important to think critically about such an assumption. I argue that many of the contradictory or difficult to understand concepts in standard quantum mechanics stem significantly from these assumptions about reality. To demonstrate this, I propose that adopting a new set of assumptions — based on non-local waves and discrete time [2] — eliminates these contradictions. By comparing phenomena explained under this new framework with those under standard quantum mechanics, I aim to validate this approach.

3 The meaning of the superposition principle from the perspective of discrete time

The superposition principle is one of the most important principles that form the basis of quantum mechanics. There are various interpretations of quantum mechanics, but they all have in common that they are based on the superposition principle.

The Schrödinger equation is linear, and the linear combinations of its solutions are also solutions. The solutions of the Schrödinger equation form a Hilbert space. Any arbitrary state of a physical system can be expressed as a linear combination of basis states in the Hilbert space. In other words, it is in a superposition state. In standard quantum mechanics, the macroscopic world is considered to be an extension of quantum mechanics, the superposition principle is considered a universal principle that applies regardless of the macroscopic world and the microscopic world.

However, the meaning of the superposition principle is quite different in the discrete-time perspective. In the discrete time perspective, the equations of electromagnetically interacting particles are determined by the following modified Dirac equation [4]. In (1), Δp_μ represents the change in energy momentum vector due to interaction during discrete time Δt

$$\mathrm{D_m}\Psi = \left(i\gamma^\mu\partial_\mu - f_{1r}\gamma^\mu p_\mu - f_{2r}\gamma^\mu\Delta p_\mu\right)\Psi = 0\,, \qquad (1)$$

where

$$\left.\begin{aligned} f_{1r} &= \mathrm{Re}\, f_1 = \frac{1}{3}\,\mathrm{Re}\,\frac{\mathrm{e}^{-ix^\alpha p_\alpha}}{\mathrm{e}^{-ix^\alpha p_\alpha} + 2\,(\mathrm{e}^{-ix^\alpha \Delta p_\alpha} - 1)} \\ f_{2r} &= \mathrm{Re}\, f_2 = \frac{1}{3}\,\mathrm{Re}\,\frac{2\,\mathrm{e}^{-ix^\alpha \Delta p_\alpha}}{\mathrm{e}^{-ix^\alpha p_\alpha} + 2\,(\mathrm{e}^{-ix^\alpha \Delta p_\alpha} - 1)} \end{aligned}\right\}. \tag{2}$$

The Hamiltonian is [4]

$$\mathrm{H} = \vec{\alpha}\cdot\left(\vec{\mathrm{p}} - q'\vec{\mathrm{A}}\right) + \beta m' + q'\phi, \tag{3}$$

$$m' = f_{1r}\, m, \quad q' = (1 - f_{2r})\, q. \tag{4}$$

In (4), m and q represent the actual mass and charge of the matter, while m' and q' are the apparent values resulting from causal delay in discrete time. The reason apparent values differ from actual values is that the effect of causal delay is viewed from a dynamical perspective, as in (3). Let us explore the physical significance of the changes in mass and charge due to causal delay in more detail. For example, consider an electron in a hydrogen atom. The electron is subject to the Coulomb force. In continuous time, the electron's mass and charge are m and $-e$, respectively, i.e., the actual mass and charge. When discrete time is applied to the electron's motion under the same electric field, the change in the electron's velocity per unit time is smaller compared to the continuous time case. This implies an increase in mass for the mass term and a decrease in charge for the charge term. Since the effect of charge is much greater than that of mass in the motion of an electron within an atom, the energy of the electron in a hydrogen atom, when considering causal delay, will be smaller than the Coulomb energy. However, at the scale of the Bohr radius, this difference is extremely small, and as calculated in the previous paper, it is about 10^{-9} smaller than the Coulomb energy [3].

The modified Dirac equation (1) is also a linear equation of the first order. However, since m' and q' are quantities that depend on the interaction energy, (3) is a kind of recurrence equation. If the interactions are Δp^1_μ, Δp^2_μ, Δp^3_μ, ... with a causal delay time Δt interval, and the Hamiltonians at each interaction are $\mathrm{H}_0, \mathrm{H}_1, \mathrm{H}_2, \ldots$, the following diagram can be expressed as

$$m'_0, q'_0\,(\mathrm{H}_0) \xrightarrow{\Delta p_1} m'_1, q'_1\,(\mathrm{H}_1) \xrightarrow{\Delta p_2} m'_2, q'_2\,(\mathrm{H}_2) \xrightarrow{\Delta p_3} \ldots \tag{5}$$

$$\left.\begin{aligned} \mathrm{H}_0 &= \vec{\alpha}\cdot\left(\vec{\mathrm{p}} - q'_0\vec{\mathrm{A}}\right) + \beta m'_0 + q'_0\phi \\ \mathrm{H}_1 &= \vec{\alpha}\cdot\left(\vec{\mathrm{p}} - q'_1\vec{\mathrm{A}}\right) + \beta m'_1 + q'_1\phi \\ \mathrm{H}_2 &= \vec{\alpha}\cdot\left(\vec{\mathrm{p}} - q'_2\vec{\mathrm{A}}\right) + \beta m'_2 + q'_2\phi \\ &\ldots\ldots\ldots\ldots\ldots\ldots \end{aligned}\right\}. \tag{6}$$

In (6), all $\mathrm{H_i}$ have their own Hilbert space. Since the Hilbert spaces of $\{\mathrm{H_i}\}$ are generally different, there is no unique Hilbert space that satisfies the entire system. This means that any arbitrary state cannot be expressed as a linear combination of basis vectors. Therefore, the superposition principle does not hold in general.

However, when the interaction is very small, (3) can be approximated as an eigenvalue problem in standard quantum mechanics, i.e., Hilbert space analysis is possible.

If $\Delta p_\mu \ll p_\mu$, then

$$m' \simeq \frac{1}{3}\, m, \quad q' \simeq \left(1 - \frac{2}{3}\,\cos \Delta x^\mu p_\mu\right) q. \tag{7}$$

For example, in the case of the electrons of a hydrogen atom, $\langle T\rangle = -\langle V\rangle/2 \sim O(m\alpha^2)$ and $\Delta t = 1/m$ [4], so

$$\Delta x^\mu p_\mu = \Delta t\left(E - \frac{\vec{\mathrm{p}}^2}{m}\right) = \Delta t\,(V - T) \sim O(\alpha^2). \tag{8}$$

Therefore, $\cos \Delta x^\mu p_\mu \sim \cos \alpha^2 \simeq 1$. Also, since the cosine function is constant near 0, we can say that the mass and charge are constant in (7). This fact means that in the case where the interaction is very small, (3) can be said to have a unique Hilbert space. In other words, (3) can be interpreted as an eigenvalue problem of the standard quantum mechanics.

To summarize, the superposition principle of the standard quantum mechanics is established only when the interaction is very small, and in this case, the system can be analyzed using the Hilbert space. However, in general cases, the Hilbert space cannot be applied, and Equation (1) merely carries the meaning of the wave equation.

4 Double slit experiment

The double-slit experiment is a simple yet practical experiment that clearly reveals the strangeness of quantum mechanical reality. Since there are various theories for interpreting quantum mechanics, there may be various perspectives on the interpretation of the double-slit experiment, but here we will compare the standard quantum mechanical interpretation and the perspective of non-local waves in the perspective of discrete time.

When a single photon is fired toward a double slit, it passes through the slits and is detected at a single point on the screen. However, if photons are fired sequentially, an interference pattern forms on the screen. From the perspective of the standard quantum mechanical view of reality, this requires the existence of a state in which a single photon passes through both slits simultaneously. In other words, the superposition principle is necessary. If the states passing through each slit are ψ_1 and ψ_2, the interference state on the screen is $\psi_1 + \psi_2$, and its probability is given by the Born rule as $|\psi_1 + \psi_2|^2$. The view of reality underlying this explanation assumes that a photon is a localized particle-like entity with a phase.

Now, let us explain this in terms of non-local waves defined in discrete time. Non-local waves propagate and produce interference phenomena similarly to local waves, but their wavefront collapses simultaneously at a single point on the screen. The wave passing through the double slits interferes on the screen, which is consistent with the behavior of local waves up to this point. However, a non-local wave behaves as if it causes the photoelectric effect as a single photon due to wave collapse from inelastic collisions with electrons of the atoms constituting the screen. The location of this reaction is determined by a probability proportional to the square of the interference amplitude. In other words, the Born rule still holds for non-local waves. In standard quantum mechanics, the square of the amplitude represents the probability of detecting a particle, whereas, in the non-local wave perspective, it represents the probability of wave collapse occurring at that point.

If the measuring device is placed at one of the double slits, the interference pattern disappears. From the conventional viewpoint, it is explained that interference does not occur because there is no state of passing through both slits at the same time. From the non-local wave viewpoint, the wave collapses due to an inelastic collision at the measuring device, and the wave proceeds again from that collapsed state, so it will have the same effect as a single slit.

The above discussion briefly examines the explanations of the double slit experiment from the two perspectives. While there is a clear difference in their views of reality, both perspectives explain the experimental results without significant issues.

5 Delayed choice experiment — wave-particle duality

The problem of wave-particle duality is a somewhat old problem in quantum mechanics, but it needs to be discussed because it raises doubts about physical reality. When discussing wave-particle duality, the concepts of wave and particle are somewhat traditional. It is somewhat different from the concept of reality used in the double-slit experiment.

There are various versions of the delayed choice experiment, but here we will first discuss the double-slit experiment proposed by Wheeler [6]. In this experiment, the light measuring device is a plate and photodetectors. The plate measures the interference pattern caused by the interference of light passing through both slits, and the photodetectors are placed facing the two slits to measure which slit the photon passes through. In other words, the former measures the wave nature of light, and the latter measures the particle nature of light. The point of this experiment is to figure out when light decides whether it behaves as a wave or a particle. It is assumed that its reality will be determined after passing through the double slits, but this thought experiment shows that this is contradictory. To see this, you have to choose the measuring device after the light passes through the double slits. Even then, if you choose the plate, you will still observe the interference pattern on the plate, and if you choose the photodetector, you will observe the particle impact.

As a simpler and more meaningful thought experiment, consider the split beam experiment introduced by Wheeler.

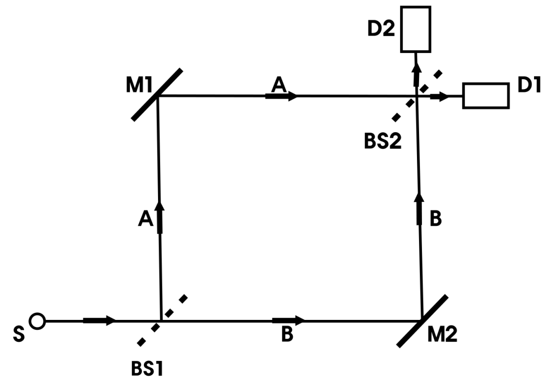

Fig. 1: Mach–Zehnder interferometer.

The experimental description of Fig. 1 is as follows

1. A single photon is emitted from a pulsating source of light S;
2. This photon reaches a semitransparent mirror BS1 and splits into two paths;
3. The first path goes to a perfectly reflective mirror M1, and the second path goes to a perfectly reflective mirror M2;
4. M1 and M2 reflect their respective beams so that they merge back together;
5. The two beams meet at a semitransparent mirror BS2, and photodetectors D1 and D2 are arranged to record the interference pattern between the two beams.

However, if the semitransparent mirror BS2 is removed during the experiment, the situation changes. Without BS2, the two beams do not merge, but proceed separately, and are directed to photodetectors D1 and D2, respectively. At this time, D1 detects the photon coming from the path through A, and D2 detects the photon coming from the path through B. In this case, the interference pattern disappears, and it is clear which path the photon took.

The key to this experiment is that after the photon passes through the semitransparent mirror BS1, the observer can choose whether to remove BS2 or leave it. If BS2 is left, an interference pattern is observed, and if it is removed, the path information is revealed.

The above thought experiments summarize that the reality of light is not determined while it is in motion, but is determined at the last moment of measurement. Wheeler says, "*No phenomenon is a phenomenon until it is an observed phenomenon*". Physical reality is not determined until it is observed, and the past is determined by observation. Reality is formed by the interaction with the observer.

Now, let us interpret these thought experiments from the perspective of non-local wave. In the discrete time perspective, it is assumed that the physical reality before measurement exists in the form of a non-local wave, and the simultaneous wave collapse caused by interaction possesses quantum properties.

First, in the double-slit experiment, choosing a plate or photodetectors as the measurement device, even if the choice is made after the light passes through the double slits, has no effect on the reality of the light as a non-local wave. A non-local wave simply causes wave collapse at the plate if a plate is present, or at the photodetector if a photodetector is present. As previously explained, wave collapse at the plate occurs with a probability proportional to the square of the interference wave's amplitude, resulting in an interference pattern. A non-local wave entering the photodetectors has an equal probability of wave collapse at each photodetector, but if wave collapse occurs at one photodetector, the collapse property of the non-local wave ensures that no observation occurs at the other detector. However, observing a wave collapse at one photodetector does not mean the light passed through a specific slit. The non-local wave always passes through both slits. Even if the photodetectors are sufficiently far from the double slits to neglect interference effects, if no collapse occurs in between, a measurement will occur at one of the photodetectors.

Next, let us consider the beam-splitter experiment. The non-local wave emitted from the light source is equally split into two paths at the partially transparent mirror BS1. The non-local waves traveling along each path meet at the partially transparent mirror BS2, where they interfere, causing a wave collapse at D1 due to constructive interference, resulting in observation. If BS2 is removed, the split light from each path reaches D1 and D2. In this case, the probability of wave collapse at each detector is 50%, so a photon is observed at either D1 or D2. Observing a photon at D1 or D2 does not mean the light traveled through a specific single path. The non-local wave passes through both paths. The fact that it is observed at only one detector is due to the collapse property of the non-local wave. The delayed choice of the measurement device made while the non-local wave travels through both paths has no effect on the physical reality of the non-local wave. The non-local wave simply undergoes wave collapse due to interaction at the measurement device.

It is indeed difficult to explain the delayed-choice experiment using the conventional concepts of waves or particles. These concepts cannot define the physical reality before observation. However, as pointed out in the previous paper, the conventional concepts of waves and particles are physical realities inferred from the macroscopic world [1]. The logic of the delayed-choice experiment, which suggests that these concepts cannot define the microscopic world before observation, is valid. However, interpreting this to mean that no determined physical reality independent of observation exists in the microscopic world is an excessive leap in logic. It is merely that the conventional concepts of waves and particles cannot define it. This paper proposes non-local waves as an alternative.

Local conservation of energy

The concept of local conservation of energy is one of the most important concepts in physics, encompassing both classical mechanics and quantum mechanics. However, this concept requires a rigorous definition when applied to the microscopic world. The wave-particle duality in the microscopic world and the concept of local conservation of energy can lead to contradictory situations.

The definitions of energy and momentum are established through interactions. These concepts may apply prior to interactions, but they can also be seen as emerging during interactions. In classical mechanics, they are always defined regardless of interactions, and the law of local conservation holds. However, in quantum mechanics, there is an issue.

Quantum mechanical reality possesses both wave and particle properties. Let us first consider the wave. Can a wave possess energy? Naturally, the energy of a photon is defined as $E = h\nu$. However, this is a concept associated with a particle. A wave spreads and propagates through space. If energy were defined for a wave, the energy of its local parts would need to be defined, which cannot explain the quantization of energy during interactions.* Furthermore, if momentum were defined for a wave, the concept of accelerated motion would need to be defined for the wave. A wave is a physical reality that propagates and interferes, not a concept that accelerates like a particle. Consequently, the concept of mass cannot be defined for a wave. Next, let us consider particle properties. A particle can naturally have mass defined. However, defining frequency or wavelength for a particle is not reasonable.

Synthesizing the above, energy and momentum cannot be defined for a wave, and frequency and wavelength cannot be defined for a particle. However, all these concepts are necessary to describe the microscopic world. The microscopic world exhibits wave-like properties at times and particle-like properties at others. However, these two properties never manifest simultaneously. This suggests that some form of transition occurs between wave-like and particle-like properties. Thus, the equation $E = h\nu$ can be interpreted as indicating that light, as a wave with frequency ν, transitions into a particle-like photon with energy $h\nu$. Here, the Planck constant can be understood as representing a kind of exchange ratio during this transition. Since this exchange ratio is constant, energy is consequently conserved. However, its meaning differs from the local energy conservation in classical mechanics.

The concept of transition between wave and particle discussed above is merely an inference derived from quantum

*In the quantum field theory, this issue is addressed by introducing the mathematical assumption of second quantization, but this is an entirely different approach.

mechanical phenomena and the definitions of wave and particle concepts. A model that aligns with this inference is the non-local wave. If the concept of energy conservation in the microscopic world is defined as above, the issue of local energy conservation arising from the instantaneous collapse of a local wave does not occur in the collapse of a non-local wave.

6 Interaction free measurement

Interaction-free measurements were first proposed in the Renninger negative-result experiment and developed into the Elitzur-Vaidman Bomb Tester [8]. This thought experiment vividly illustrates how our notions of physical reality significantly influence the understanding of phenomena. The components of this experiment are as follows. It uses the Mach-Zehnder Interferometer shown in Fig. 1 and applies the concept of physical reality from standard quantum mechanics. The bomb is placed in path B and explodes upon interaction with a photon. The bomb can be in a "live" (functional) or "dummy" (non-functional) state.

How the interferometer works:

1. The photon splits into two paths (A and B) at BS1;
2. Along each path, it passes through mirrors (M1, M2) and is recombined at BS2;
3. At BS2, the photon is designed to reach only a specific detector (D1 or D2) due to interference effects. For example, if the interferometer is well tuned, the photon will always reach D1 and never reach D2.

The key to this experiment is to obtain information about whether a bomb is on path B without having the bomb directly interact with the photons (i.e. explode).

(1) In the absence of a bomb

When a photon reaches BS1, the wave function splits into two paths, A and B. The photon travels along the two paths and rejoins at BS2. Due to the interference effect, the photon always reaches D1 and never reaches D2. This is because constructive interference occurs at D1.

(2) If there is a bomb (live bomb)

Let us assume that there is a functional bomb in path B. This bomb explodes with 100% probability if it absorbs a photon. When a photon passes through BS1, the wave function still splits into two paths. However, if the photon interacts with the bomb in path B, an explosion occurs, and it is not observed at the detectors. This case occurs with a 50% probability (the probability that the photon chooses path B).

Conversely, if the photon chooses path A (50% probability), it does not interact with the bomb. In this case, the wave function collapses to path A. The photon then travels along path A and reaches BS2. BS2 splits the photon again with a 50:50 probability, sending it to either D1 or D2. Thus, the photon reaches D1 with a 25% probability and D2 with a 25% probability.

(3) In the case of a bomb (dummy bomb)

The dummy bomb has no sensors in the path of the photon. Therefore, it does not interact with the photon and behaves the same as in the case without the bomb. The photon always reaches D1 and never goes to D2 due to interference effects.

The critical aspect of this experiment is the detection result at D2. If D2 clicks, it definitively indicates that the bomb is in a live state, yet the photon did not interact with the bomb at all during this process. This is because the photon took path A, so it had no opportunity to encounter the bomb. However, the presence of the bomb (in its live state) eliminates the wave function component in path B, disrupting the interference and creating the possibility for D2 to click. In other words, the mere existence of the bomb induces the collapse of the wave function, altering the interference pattern. This conclusion demonstrates that measurement does not necessarily require a physical interaction between the particle and the detector.

The above is the conventional interpretation of the Elitzur-Vaidman Bomb Tester. However, before reaching such a conclusion, we must consider the quantum mechanical reality assumed in this interpretation. The non-local wave hypothesis offers a completely different interpretation of this experiment. In conclusion, all measurements originate from interactions.

The non-local wave incident on BS1 is divided into two paths:

(1) If there is no bomb, the waves passing through each path interfere at BS2, and due to constructive interference, wave collapse occurs at D1, where the photon is observed;

(2) If there is a bomb, the probability that wave collapse will occur by reacting with the bomb in path B is 50% because the wave is divided into two paths. When wave collapse occurs, the wave traveling along path A disappears simultaneously and acts as a single photon in the bomb. In this case, photon cannot be observed in either D1 or D2.

So, what happens in the remaining 50% probability where collapse does not occur? The collapse of a non-local wave occurs when an energy change is induced by an inelastic collision [2]. If the wave incident on the bomb undergoes elastic collision, there is no energy change, and thus, the photoelectric effect caused by light does not occur at the bomb's sensor. Naturally, this case does not result in an explosion. If only path B existed without path A, the bomb's sensitivity is assumed to be 100%, meaning it would definitely explode. However, with path A present, only 50% of the wave passes through path B, so the probability of the bomb exploding is also 50%. This eliminates the need to redefine a new probability for the bomb's sensor to trigger an explosion. Therefore, in the 50% probability where an explosion does not occur, 50% of the wave travels along path A, and the remaining 50% undergoes elastic scattering at the bomb. The 50% that travels along path A reaches BS2, where it is split into D1 and D2 with a 25% probability each, and wave collapse occurs at one of the detectors with a 25% probability. The 25% probability of wave collapse occurs because only 25% of the original wave reaches the detector. When a non-local wave collapses, all wavefronts collapse simultaneously at a single point. The location of the remaining 75% of the wave is irrelevant. Consequently, interactions always occur in quantum units.

(3) In the case of a dummy bomb, as discussed above, photons will be observed at D1 by constructive interference, just as in the case of no bomb.

The crucial point in the above discussion is that the photon observed at D2 with a 25% probability is not devoid of interaction with the bomb. The light that splits at BS1 and travels along path B undergoes an interaction with the bomb through elastic scattering. According to the conventional view of reality in standard quantum mechanics, it is interpreted as having no interaction, but from the perspective of non-local waves, an interaction is considered to have occurred.

7 Measurement problem

According to standard quantum mechanics, the state of any physical system defined in a Hilbert space can be represented as a superposition of basis states, and this state evolves deterministically according to the Schrödinger equation. However, measurement causes the system's state to collapse into a single basis state. This process occurs probabilistically according to the Born rule and is a non-unitary process that is not predicted by the Schrödinger equation. Yet, this measurement principle is empirically based, and its foundation remains unclear. Currently, various interpretations, from objective collapse theories to epistemological interpretations, attempt to explain it, but none are definitive.

In contrast, from the new perspective of non-local waves in discrete time, the superposition principle does not generally hold. The system's state cannot be represented as a linear combination of basis states in a unique Hilbert space. The state of a single-particle system, before interaction, is a uniquely determined non-local wave. When the wave collapses due to an interaction accompanied by an energy change, it becomes a Compton sphere with a determined mass and size. Therefore, from this perspective, the measurement problem itself does not arise.

As suggested in the previous paper, quantum waves do not exist in systems above the Planck mass [1]. Thus, discussing superposition for physical objects in the macroscopic world is meaningless. That is, Schrödinger's cat is not a controversial issue at all.

8 Conclusions

The title of this series of papers, "Interpretation of Quantum Mechanics", may seem somewhat inappropriate. While the various existing interpretations of quantum mechanics differ significantly in their perspectives, they share a common foundation: the superposition principle, one of the most fundamental axioms of standard quantum mechanics. However, in the discrete time perspective, the superposition principle generally does not hold, making many claims in these papers appear to fall outside the scope of quantum mechanics. Nevertheless, even though the superposition principle does not generally apply, it is approximately satisfied in systems with very small interactions, so this can be seen as an extension of standard quantum mechanics.

This paper argues that many problems in standard quantum mechanics stem from two main aspects. The first is the ontological assumption about physical reality. The way physical reality is perceived fundamentally alters the physical interpretation of phenomena and the direction of research.

The second issue is the superposition principle. This principle is the most important in quantum mechanics but also causes several problems. However, in the discrete time perspective, this principle is considered to hold only in specific cases in the microscopic world, so the measurement problem, as seen in standard quantum mechanics, does not exist.

Let us consider another example where these two aspects are prominently revealed. Recall the double-slit experiment discussed earlier. According to the conventional view of reality, a state exists where a particle passes through both slits simultaneously, necessitating consideration of a superposition state of gravity caused by the particle. This leads to the need for a theory of quantum gravity. The assumptions underlying this logic are the ontological assumption about matter before interaction — namely, that matter is a localized entity with particle-like properties — and the superposition principle. In other words, the notion is that matter before observation can exist in "this place" and "that place" simultaneously. However, as argued in this paper, if these two assumptions are incorrect, this notion does not hold, and consequently, the necessity for a quantum gravity theory is significantly reduced.

On the other hand, what about the non-local wave perspective? When a non-local wave passes through the double slits, it is a determined wave, and the concept of a superposition state is unnecessary. In the case of matter, when the non-local wave collapses to form a Compton sphere, the collapse position is probabilistically determined by the Born rule, and this sphere has a determined mass and size. Therefore, from this perspective, the concept of a superposition state of gravity does not apply.

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