Original Paper

Meaning of the Wave Function and the Origin of Probability in Quantum Mechanics

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Received: 5 April 2019 / Accepted: 5 September 2019 / Published online: 30 September 2019

Abstract: Microscopic objects have a definite spatial distribution that affects quantum phenomena. The particle model is not suitable for describing the microscopic world. Therefore, we use the rotating field matter sphere model, whose size is automatically variable due to different motion states, and is coordinated with the special theory of relativity. Thus, constructing a dual 4-dimensional space-time description of microscopic quantum phenomena has obvious theoretical advantages. In the dual 4-dimensional space-time, the matter wave is a physical wave. The quantum probability originates from the tangible structure and mass density distribution of the micro-object, and is reflected in the transformation of physical space-time. Matter waves and probability waves can be transformed by Fourier transformation.

Keywords: Field matter sphere; matter wave; quantum probability; transformation of representation

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1. Introduction

Among the many puzzles of quantum mechanics, the physical meaning of wave function and the origin of quantum probability are the two major problems that everyone cares about the most. So far, there have been heated discussions with different opinions [1]. Regarding the physical meaning of wave function, the Realist School takes Einstein as its representative, Debroglie and Schrodinger as its main members, and holds that wave function itself has physical meaning, and that wave function describes physical reality [2]; the Non-deterministic School takes Bohr as its representative, and Bonn, Heisenberg and Dirac as its main members and holds that the function itself has no physical meaning. It describes the probability distribution of micro-particles. The square of absolute value of wave function describes the probability density of micro-particles appearing in space-time [2][3], so wave function is the knowledge of cognitive world (cognitivism).

In the debate, later scholars, namely the so-called mathematical realism, even directly believed that the wave function itself was real. Guo Guang-can, a scholar, holds this view [4]. Thus, there are two completely opposite opinions about the source of quantum probability. The group represented by Einstein believes that quantum probabilities originated from external uncertainties and were later identified as "Hidden Variables" by Bohm [5]. God does not roll dice. The other school, represented by Bohr, believes that the microscopic particles themselves have "natural" uncertainties, and the quantum probability originates from the nature of particles [6]. In addition, there are subsequent quantum probabilities that originate from motion uncertainty and quantum probabilities originating from the dry winding of external spurious signals, and so on [7].

France's Thom [8], Japan's Sakata Shyoichi [9] and Yukawa Hideki [10] all believe that the difficulty of quantum mechanics is the fault of the point model. They think that in the micro field, we cannot treat the microcosmic objects as the point particles, and what models are appropriate , they don't make it clear. The once superb superstring theory is also a non-point model theory. But today, the development of string theory has encountered great difficulties - mathematics is too complicated, physical connotation is insufficient - it is difficult to continue to develop [11].

At the Basic Symposium on Quantum Mechanics in Shanxi last year, Professor Peter J. Lewis of United States Dartmouth College revolved around the measurement leading to collapse, pointing out three main viewpoints of realism on Spontaneous collapse, pilot wave theory and Many worlds theory. However, the defects of these models also lead to problems that are difficult to solve, such as insufficient determinism, non-locality, probability, dimension, and self-interaction. In response to the dilemma of realism, cognitivism proposes that the wave function is not a description of the world, but a theory of information, knowledge and belief. The path of the four theories are respective ψ-Cognitivism, Quantum Information, Quantum Bayes (Quantum Bayesianism) and Quantum pragmatism. Professor Lewis also expressed some concerns about interference [12].

Our solution is to abandon the point model and use the rotating field matter sphere model to establish a dual 4-dimensional space-time description of the microscopic quantum phenomenon. In the dual 4-dimensional space-time, the wave function describes the physical wave. The quantum probability originates from the tangible structure of the microscopic object, the matter density distribution and the transformation from the dual 4-dimensional space-time to the classical space-time description. Quantum measurement can promote this spatiotemporal transformation, and matter waves evolve into probability waves [13]. This will be of great significance for an in-depth discussion of quantum measurement, quantum entanglement, and the physical nature of quantum communication.

2. The mathematical basis of dual 4 - dimensional space-time

2.1. Complex number description of the sphere

- Coordinates of complex space

$$
\begin{gathered}
Z = x + iy = re^{i\theta} \\
r = r(x,y) \qquad (1\text{-}1) \\
r = (x^2+y^2)^{1/2}
\end{gathered}
$$

Describes the complex space spherical coordinates and the center of the sphere at the origin of the coordinates.

- The mapping space of complex number Z

$$W=1/Z^{*}=Ae^{i\theta}=u+iv \tag{1-2}$$

$$W^{*}=1/Z=Ae^{-i\theta}=u-iv \tag{1-3}$$

$$A=1/r\,,\quad |A|^2=u^2+v^2 \tag{1-4}$$

$|Ae^{i\theta}|^2=|A|^2=1/r^2$ is the curvature of the sphere. For the convenience of discussing wave functions, we abbreviate the curvature of the great circle A=1/r as curvature of field matter sphere [14].

2.2. Complex sphere

Quantum wave function ψ is complex function. Complex numbers can be defined on complex sphere [15]. See figure (1).

(1)sphere of c

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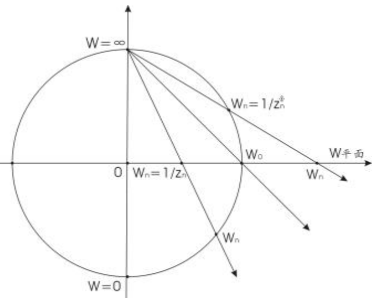

(2-1)

$$W^{*}=1/Z=Ae^{-i\theta}=u-iv \tag{2-2}$$

$$|A|^2=u^2+v^2 \tag{2-3}$$

- In complex numbers $W=1/Z^{*}=A\,e^{i\theta}$, $A=1/r$, when $r\to 0$, $|Z^{*}|\to 0$, $W\to\infty$, It's the North Pole singularity; $r=0$, $|Z^{*}|=0$, W no defined. It mapping out of the sphere and becomes a geometric point in real space.

- The evolution of **microcosmic** object and radius of curvature (curvature). If complex numbers $Z=x+i\,y=r\,e^{i\theta}$, ordered $r=R$, while R is the curvature radius of the microcosmic object sphere model "great circle", $A=1/r=1/R=k$, and $k=1/R$ is defined as the curvature of the microcosmic object. $R\to 0$, $k\to\infty$; $R=0$, $k=\infty$, is a particle, exactly corresponds to a geometric point in real space. The curvature model of complex space becomes the particle model of real space. In complex space, when $0<r\leqq r_0$, $k_0\leqq k<\infty$ and $0<R\leqq R_0$, $K_0\leqq k<\infty$ microcosmic objects appear as matter waves; $K_0=m_0c/\hbar$ is known as the quantum curvature of the microcosmic object, while the matter wave mapping to real space present a probability distribution of point particles.

- The physical mechanism and significance of the mapping inside and outside the complex sphere. The K space of the microcosmic object itself, through the curvature $k\to\infty$, R=0 (or h $\to$0), compacts into zero dimension, and the hidden freedom dimension are hidden again, becoming point particles in the 4-dimensional real space. The undulating motion of the microscopic object evolves into the point particle motion of the microscopic object, either trajectory or probability. Thus, quantum mechanics returns to classical mechanics or classical statistical mechanics.

2.3. Dual quaternions complex space, dual 4-dimensional complex phase space, dual 4-dimensional complex space-time

- Dual quaternions complex space. Definition:

$$Z_\mu = x_\mu + iy_\mu \ , \ Z^*_\mu = x_\mu - iy_\mu$$

$$W(x,y) = 1/Z^* = u(x,y) + iv(x,y) = Ae^{i\alpha} \tag{3-1}$$

$$\psi(x,y) = u(x,y) + iv(x,y) = A(x,y)exp(-iy_\mu x_\mu)$$

Here y_μ, x_μ are dual quaternions complex space virtual and real space coordinates,it appearing in the phase of the wave function.

- Dual 4-dimensional complex phase space

A dual 4-dimensional complex phase space can be defined by (3-1). When x_μ is the 4-dimensional component of the vector $\boldsymbol{x}$, and y_μ is the 4-dimensional component of the vector $\boldsymbol{y}$

$$x_\mu = (x_1, -x_2, -x_3, -x_4)$$
$$y_\mu = (y_1, -y_2, -y_3, -y_4) \tag{3-2}$$

Then $Z_\mu = x_\mu + iy_\mu$ can be regarded as the vector x, y generated by the dual 4-dimensional complex phase space.The wave function:

$$\psi(x,y) = u(x,y) + iv(x,y) = A(x,y)exp(-iy_\mu x_\mu) \tag{3-3}$$

Formula (3-3) is a wave function in a dual 4-dimensional complex phase space, which has the same form as the wave function in Formula (3-1). However, the coordinates of the phase space x, y are components of the vector $\boldsymbol{x}$ and $\boldsymbol{y}$, which have the properties of the vector $\boldsymbol{x}$ and $\boldsymbol{y}$, but the phase angle $y_\mu x_\mu$ must be dimensionless.

- Dual 4-dimensional complex space-time. If the vector $\boldsymbol{x}$ has the probability attribute, then the dual 4-dimensional space time has the probability attribute, if the vector component x_μ one has the time attribute, then the dual 4-dimensional complex phase space x_μ, y_μ is called the dual 4-dimensional space-time [13].

3. Geometric construction, wave function and description space of microcosmic objects

3.1. Geometric construction of microcosmic objects:

Studies have shown that modern physics cannot locate the spatial coordinates of **microscopic** objects smaller than the Compton wavelength [16], and this is the experimental basis for the creation of the field matter sphere model by the dual 4-dimensional space-time quantum mechanics. The **microcosmic** object is "the field matter sphere with uniform mass distribution of rotation", which has a certain spatial distribution. Position $\boldsymbol{x}$ has an uncertain property for the **microcosmic** object .The state of **microcosmic** objects [13] :

- Static geometry description: the radius of curvature is

$$R_0 = \hbar/m_0c \tag{3-4}$$

Definition m_0 is the static mass of the matter field, and R_0 presents the extension distribution of the "internal" matte wave field of the static **microcosmic** object. And the curvature is given by K_0

$$K_0 = 1/R_0 = m_0c/\hbar \tag{3-5}$$

Definition K_0 is a symbol of particle nature. R_0 and K_0 are invariants relative to any stationary reference frame, independent of spatial position. It is not directly observable, but it is real, similar to the physical noumenon, and K_0 is called the quantum curvature of the **microcosmic** object.

- Dynamic geometry description. The radius of curvature is defined as

$$R_1 = \hbar/mc \tag{3-6}$$

Curvature is defined as

$$k_1 = 1/R_1 = mc/\hbar \tag{3-7}$$

Where m is the quality of exercise, moving mass, mass m increases, radius of curvature decreases, and curvature increases. The matter sphere of the sports field is a quantum object with a variable shape. In the translation and spin, the edge velocity of the ball is guaranteed to not exceed the speed of light, which is coordinated with the theory of relativity. It is a physical entity in the physical theory, known as "phenomenal entity" in the interaction realism [17].

- Three-dimensional space mapping. The radius of curvature is defined as

$$R_i = \hbar/mv_i \tag{3-8}$$

The curvature is defined as

$$k_i = mv_i/\hbar \tag{3-9}$$

$p_i = mv_i$ is relativistic momentum, three dimensional observable.

It can be seen that the "mapping" of microcosmic objects in 3d observable space has a radius of curvature that can be very large or very small, similar to the understanding of wavelength. It is different from the spatial structure R_0 and R_1 of microcosmic objects, and is similar to an "image" [18]. If the momentum and energy of microcosmic object are obtained in electromagnetic field, we call it electromagnetic curvature or electromagnetic quantum curvature.

- Rotation frequency is defined as

$$\nu_0 = E_0/h,\ \nu_1 = E/h\ ,\ (\nu_i = E_i/h) \tag{3-10}$$

$E_0 = m_0c^2$, $E = mc^2$, ($E_i = m_0 v_i^2/2$ or $E_i = mv_i^2/2$) are consistent with the basic assumptions of quantum mechanics and relativity.

- Field matter density is defined as

$$\eta = m/V = \eta(k) \tag{3-11}$$

V is the volume of the field matter sphere, V=V(R), R=R(k), the density η of the matter field is a function of the curvature k, k = k_0, k_1, k_i, ($\mathbf{k_1} - \mathbf{k_i} = \mathbf{k_0}$). It can be proved that the density of the matter sphere increases along with the decrease of V and the increase of k. The matter sphere V increases, k decreases, the density of the matter sphere decreases, $\eta(k)$is positively correlated with k.

According to our understanding, R_0, R_1 should not be less than the Planck length, the f field matter density and energy density of field matter sphere can not be infinite. Avoids the infinite difficulties of point particle theory.

3.2. Description of coordinate complex space and curvature complex space of field matter sphere [13]

- The coordinate complex space (1-1) describes the complex space spherical coordinates of the spherical center at the coordinate origin.If the modulus r of the above complex number is defined by the curvature radius R of the microscopic object, and R = r, then the spherical coordinates of the above complex space describe the spherical coordinates of the **field matter sphere** with radius R, and

$$R = R(x,y),\ \ R = (x^2+y^2)^{1/2} \tag{3-12}$$

Static microscopic object: $R=R_0=\hbar/m_0c$, **microcosmic** object of movement: $R=R_1=\hbar/mc$, mapping in three dimensions: $R = R_i = \hbar/mv_i$. The field matter sphere is described in coordinate complex space.

- Curvature complex space.The curvature complex space is introduced

$$W=1/z^{※}=u(x,y)+iv(x,y)=(1/r)e^{i\alpha}=ke^{i\alpha},\ k=1/r \tag{3-13}$$

W is the mapping space of Z, describing the spherical coordinates of curvature sphere with the center of the sphere at the origin of coordinates and the module $k(x, y) = 1/r$. Similarly, if k is defined by the curvature $k = 1/R$ of the field matter sphere of the microcosmic object, then the curvature complex space W describes the curvature sphere spherical coordinates of the field matter sphere with radius R, curvature k. Static microcosmic object: $k = K_0 = 1/R_0$, moving microcosmic object: $k = k_1 = 1/R_1$, 3d space mapping: $k = K_i = 1/R_i$.

For the Z space, the matter wave field is in the sphere and out of the sphere is empty. It can be simplified into a particle at a macro and large scale. For the mapping space W, the matter wave field is mapped to the outside of the sphere through the curvature sphere, showing a global spatial distribution, and the inside of the sphere is empty. Relative to the field matter sphere, Z space and W space map to each other to describe the same matter wave field, similar to the dual hypothesis. All the wave functions in quantum mechanics are described in this space.

The full space distribution of wave functions in quantum mechanics is accomplished unconsciously in this kind of space transformation. The full space distribution of electrons in 4-dimensional real space is not real. But in the transformation of inner and outer space, it is necessary to facilitate the application of mathematics and physics in theoretical description, as well as the description of quantum phenomena.

In real space time, we use the motion of the particle to describe the orbital motion or probability distribution of the object. In complex space, the motion and change of curvature radius R and curvature k are used to describe the matter waves of microcosmic objects. Matter wave is the wave motion of the density or spatial structure of the field inside the microcosmic object. That's the physics of the microcosmic object not orbiting.

The introduction of curvature k is an expansion of the physical meaning of wave vectors, the geometrization of matter, and the revelation of the degree of freedom of point model hidden space, which can be attributed to the property of quantum mechanics describing space-time. The motion state of the matter wave field is related to the interaction of the microcosmic object.

3.3. Enlightenment of relativistic energy formula

From the relativistic energy formula of the microcosmic object

$$E^2=(mv_i)^2c^2+m_0^2c^4,\quad (mc)^2=(mv_i)^2+(m_0c)^2 \tag{3-14}$$

we get the momentum triangle:

$$p_1^2=p_i^2+p_0^2 \tag{3-15}$$

and the curvature triangle:

$$k_1^2=k_i^2+K_0^2,\ i=2,3,4 \tag{3-16}$$

and the vector relation:

$$\mathbf{K_0 = k_1 - k_i} \tag{3-17}$$

By k_1 and k_i, the 4-dimensional curvature space K and the 4-dimensional coordinate space x, which are related to the microcosmic object itself, can be constructed.

The 4-dimensional curvature space K

$$k = K(k_1 - k_2 - k_3 - k_4) \tag{3-18}$$

The 4-dimensional coordinate space x

$$x = x(x_1 - x_2 - x_3 - x_4) \tag{3-19}$$

The spatial invariant of the four-dimensional curvature K is given by equation (3-5) and

$$K_0^2 = k_1^2 - k_2^2 - k_3^2 - k_4^2$$
$$(dK_0^2 = dk_1^2 - dk_2^2 - dk_3^2 - dk_4^2) \tag{3-20}$$

Invariant of the 4-dimensional coordinate space x

$$x_0^2 = x_1^2 - x_2^2 - x_3^2 - x_4^2$$
$$(d\, x_0^2 = dx_1^2 - dx_2^2 - dx_3^2 - dx_4^2) \tag{3-21}$$

K, ***x*** space is a dual 4-dimensional flat space. dK_0, dx_0 are the invariants of two 4-dimensional coordinate transformations. It just reflects the existence of the microcosmic object--physical noumenon which does not depend on the transformation of time and space. dx_0 is the projection of $d\,k_0$ onto four dimensional space x. Through the field matter sphere model, the spatial distribution characteristics of the microscopic objects themselves can be combined with their coordinate space to construct a dual 4-dimensional complex phase space W(x, k) to describe the microcosmic quantum phenomena. Where, the variable k is the special case of $y=k$ in formula (3-1)[13].

3.4. matter wave function in dual 4-dimensional space-time

The radius and curvature of the rotating microcosmic object can be constructed from the "static" Compton momentum m_0c. In the curvature complex space, the coordinate system of the microcosmic object itself, a matter wave function [13]:

$$\Psi_0 = A_0 e^{-i\omega 0 t 0},\ m_0c^2 = h\nu_0 \tag{3-22}$$

t_0 is the coordinate time of the microcosmic object itself. Observe the uniform motion from rest, the Lorentz transformation: $t_0=(t-vx/c^2)/(1-v^2/c_2)^{1/2}$, in the observation system K, see the plane wave

$$\Psi = Ae^{-i\omega t} = Ae^{-i(\mathbf{p}x - Et)/\hbar} = Ae^{-i(kixi - k1x1)} = Ae^{-ik\mu x\mu} \tag{3-23}$$

in $i=2, 3, 4$; $\mu=1, 2, 3, 4$; $k_1x_1 = mc^2t/\hbar = (mc/\hbar)ct$. Equation (3-23) identical to the mathematical form of the wave function in quantum mechanics. But it's a matter wave -- a fluctuation of a field matter, is a physical wave. Where, x_1=ct has a time attribute, and we define the phase space $k_\mu x_\mu$ as dual 4-dimensional complex space-time W(x, k). In the equation (3-23), The complex phase space $k_\mu x_\mu$ is the space-time, where the matter wave is located, and corresponding to the position vector and curvature vector of the field matter sphere model, containing attribute of x vector and k vector. Relativity and quantum mechanics are also unified from the source of physical models. The amplitude A (x, k) of Matter wave function Ψ (x, k) is function of x and k, A (x, k) containing matter information of microcosmic object. Among them, *x* representation has probability attribute and *k* representation has matter density attribute.

The spin state of the microcosmic object is described in its own coordinate system, independent of the space-time coordinate *x*. In the spin pure state, the spin is parallel to the spin upward and downward, and has coherence [18][19].

4. Origin of quantum probability in dual 4 dimensional space-time

4.1. Uncertainty of microcosmic object position

The microscopic object is not a point, but a rotating field matter ball with uniform mass distribution and a certain spatial distribution radius R, and its position X has an uncertainty property. The uncertainty D depends on the size of R. If the quality is determined, the smaller the microscopic quantum object, the greater the matter density and the smaller the position uncertainty D. Conversely, if the same microscopic quantum object R is larger, the matter density is smaller, and the position uncertainty D is larger. This is an objective fact, and is manifested in microcosmic quantum phenomena at different cognitive levels.The uncertainty D is defined as follows:

- $R=0$, mass density $\eta=\infty$, particle model can be used, position is completely determined, uncertainty $D=0$, probability of microcosmic object at *x* is $p=1$;
- $R=\infty$, mass density $\eta=0$, position *x* is completely uncertain, uncertainty $D=\infty$, the existence of microcosmic object cannot be found, probability of appearance at *x* is $p=0$;
- In dual 4-dimensional space-time quantum mechanics, the field matter sphere has a certain size, the uncertainty of position $0<D<\infty$, and the probability of occurrence at *x* $0<p<1$.

Microcosmic quantum object is definitely not a mass point and has a certain spatial distribution radius R. Therefore, it is an objective fact that the position of microcosmic quantum object *x* is uncertain, which is manifested in quantum phenomena at different cognitive levels.

The above cognition is the physical source of uncertainty relation$\Delta x \cdot \Delta p=h$ of quantum mechanics.Dual 4-dimensional space-time reflected in the $\Delta x=2R$, $\Delta p=m_0c$, or $R k=1/2$. The values of R and k are: $0<R<\infty$, $0<k<\infty$, special case, $k=\infty$, $R=0$, $k=0$, $R=\infty$, uncertainty relation is easy to understand.

Classical space-time, the point of space-time is deterministic. In the quantum mechanics of the point particle model, the objective uncertainty of the position *x* of the microcosmic quantum object mentioned above can be subjectively understood as that in the microcosmic quantum object, at the position x_n (n=1, 2, 3...) the probability of finding the point particle. If the quality is determined, the smaller the microscopic quantum guest is, the larger the field matter density is, and the greater the probability of finding the point particle; if the microscopic quantum object is larger, the field matter density is smaller, and the probability of finding the point particle is smaller. The microcosmic quantum object contracts to a point, and the density of field matter is equal to infinity. If the space-time point and the particle coincide, the probability of finding it is 1. Microcosmic quantum object infinite, field matter density =0, probability of finding is zero.

Nevertheless, in classical mechanics, however, a particle corresponds one-to-one to a point in space and time. The microcosmic quantum is treated as a classical particle, and there is no uncertainty of position *x*. Therefore, traditional point particle quantum mechanics has formed two subjective cognitive routes: one is to admit the certainty of the spatial coordinate *x*, then point particles themselves must assume the above probability properties, so that the microcosmic quantum objects have "natural" motion uncertainty. Bohr is the representative of this cognitive line. Second, there is no uncertainty in the microcosmic object itself. The above objective uncertainty given the space-time coordinates, and space-time itself has the attribute of uncertainty. In fact, Einstein is the representative of this cognitive line. Einstein did not recognize the probabilistic nature of space and time. The responsibility lay with god, who rolled the dice.

The two ways of thinking are different and discussed in the same classical physics point particle model, but the logical starting point of reconciling contradictions cannot be found. Various alternative theories of covert point particle model have been endlessly debated, and discussions are still ongoing [15].

In the quantum mechanics dual 4-dimensional space-time W(*x, k*), the physical model is not the point particle, but a rotating field matter sphere with a certain mass and uniform distribution. The real and imaginary parts of W(*x, k*) are both maps of the field sphere. Reflect the basic attributes of microcosmic object matterity.

In W(*x, k*), the spatial freedom degrees of hidden by point particles are replaced by quantum curvature k, forming the imaginary part of the space-time of dual 4-dimensional quantum mechanics, which is associated with matter density. The *k* presentation of wave function has the **attribute** of matter density. X presentation the position of microcosmic objects, which constitutes the real part of quantum mechanics' dual 4-dimensional space-time, and **endow** *x* **indeterminacy attribute**. X presentation of wave function has probability **attribute**. The dual 4-dimensional space-time transforms the subjective cognition of the physical structure of microcosmic objects into the attribute of the dual 4-dimensional space-time.

The rotation field the interior of the matter sphere is like a rotation vector field, and there is a fluctuation of the matter field, which happens to be within the category of position uncertainty. The concept of "position uncertainty" and "mass density" has been transformed into the **attribute** of space-time and the fluctuation of its internal matter waves in space-time. The fluctuation motion of internal local area matter wave can be mapped to the motion of the universe matter wave in the complex space with external curvature through the complex number transformation W=1/z※. This enables the objective description of the quantum wave phenomenon of the microcosmic object by the dual 4-dimensional space-time quantum mechanics. Neither Einstein's dice of god nor the subjective knowledge of the uncertain nature of Copenhagen particles is needed. The dependence of quantum phenomena on subjectivity can be eliminated by the description of microcosmic quantum phenomena by quantum mechanics double 4-dimensional space-time W*(x, k*).

Since the space of the microcosmic object itself in the dual 4-dimensional space and time has a quantized characteristic and a complex quantized structure, quantum mutation makes the space-like space be distributed among them (quantum mutation time t=0)[20]. Here, we don't need to specially quantize space-time. The quantization of dual 4-dimensional space-time is with the itself of the definition, which avoids all kinds of difficulties in the quantization of classical space-time, especially gravitational space-time.

In the dual 4-dimensional space and time, microcosmic objects mapped to the real part, appears the probability density distribution of microcosmic objects, but the probability distribution is not equal to 0 and 1, and the mapped to the imaginary part, forms the field matter density distribution, but the matter density distribution is not equal to 0 and ∞. The distribution of the density of matter and the distribution of the probability density can also presentation conversion by the Fourier conversion, matter waves are converted into probability waves. How to realize the probabilistic motion of matter wave to point particle in quantum mechanics is the task of quantum measurement.

The probability is equal to 1, and the distribution of matter density is equal to infinity. For the corresponding particle model, we will go back to the laboratory to observe the probabilistic motion of particles in space. This is what classical space-time describes.

The macroscopic classical instrument is designed and manufactured by the classical point particle model theory. It is responsible for translating the microcosmic quantum phenomena described by the sphere model in the dual 4-dimensional space-time into the classical physical phenomena in the macroscopic classical space-time by properly introducing continuous interaction, and displaying the observation results of point particles [21].

The dual 4-dimensional space-time combines Bohr and Einstein's two cognitive routes into a dual 4-dimensional space-time. Formation: matter tells space-time how to have probabilistic properties, and space-time tells matter how to move probabilistically. Quantum phenomena have been completely described in a reasonable physical way [22].

Since the matter wave is formed by the motion of the rotating field matter sphere, and in the dual 4-dimensional space-time, and the amplitude A of the matter wave is function of x and k, the above qualitative analysis of the probability origin can be quantitatively described by the amplitude A(x, k) of the matter wave.

4.2. Physical properties and space-time metric of dual 4-dimensional space-time W(*x*, *k*)

- Vector: ***k*** ($k1$, $k2$, $k3$, $k4$) describes the spatial structure of the microcosmic object, presenting the existence form and matter density distribution of the microcosmic object;
- Vector: ***x*** (x_1, x_2, x_3, x_4) describes the location of the microcosmic object, and the uncertainty attribute (or probability attribute) is related to the spatial distribution and matter density distribution of the microcosmic object.
- **X** and ***k*** can form the complex vector phase space -- W(x, k) space, describing the microcosmic quantum phenomena.
- The metric tensor of dual 4-dimensional complex space-time W(x, k)

$$g^{\mu\nu}=diag(1, -1, -1, -1)$$

$$x^2=x_\mu g^{\mu\nu}x_\nu=x_1^2-x_2^2-x_3^2-x_4^2 \tag{4-1}$$

$$K^2=K_\mu g^{\mu\nu}K_\nu=k_1^2-k_2^2-k_3^2-k_4^2$$

$$|Z|^2=ZZ^{※}=x^2+y^2,\ |Z|^2=ZZ^{※}=x^2+k^2$$

are Lorentz invariants. So, we consider W(x, k) is a complex number expand of $M^4(x)$. Dirac equation is invariant in Lorentz conversion.In coordinate conversion dK_0 (dK_0^2 = dk_1^2-dk_2^2-dk_3^2-dk_4^2) is the invariant in 4-dimensional imaginary space. It is the physical noumenon of people expect. In the 4-dimensional real space dx_0 is the projection of dK_0(dx_0^2 = dx_1^2-dx_2^2-dx_3^2-dx_4^2), and dx_0 is the invariant in coordinate conversion.

Clearly, the Galileo transform is still a special case of the Lorentz transform in dual 4-dimensional space-time. The unity of classical mechanics and quantum mechanics is led by the change of physical model and the evolution of space-time metric. The invariance of Dirac equation will also transition to the invariance of Schrodinger equation.

4.3. Application of wigner function method

Matter wave function Ψ (*x, k*) of microcosmic object is a physical wave, and the movement satisfy Dirac equation (or the Schrodinger equation). The amplitude A(*x, k*) contains matter information of the microcosmic object. And there is a transformation relationship

$$A(x,k)=\int^{\infty}_{-\infty} d\xi e^{-i\xi k}\Psi^{※}(x-½\xi)\Psi(x+½\xi) \tag{4-2}$$

$$A(x,k)=\int^{\infty}_{-\infty} d\xi e^{-i\xi x}\Phi^{※}(k-½\xi)\Phi(k+½\xi) \tag{4-3}$$

Among them, the Ψ (*x*) as the position representation, Φ (*k*) for matter density representation.

If going to integrate both of these, (4-2) to eliminate variable *k*, and matter waves Ψ (*x, k*) is mapped to the real space. Get the position presentation wave function Ψ (*x*) and probability density distribution function ρ(*x*)

$$\int^{\infty}_{-\infty} A(x,k)dk=|\Psi(x)|^2=\rho(x) \tag{4-4}$$

Normalized representation

$$\int_{\tau} c\rho(x)\, d\tau=\int_{\tau} c|\Psi(x)|^2 d\tau=1 \tag{4-5}$$

Position *x* with probability attributes, ρ(*x*) is a microcosmic object at the *x* appears the probability density, define Ψ (*x*) is a probability amplitude is understandable. In the dual 4-dimensional space-time , define $|\Psi(x)|^2=\rho(x)$ for probability density, physical background is clear. This is space-time telling matter how to move probabilistically. Since the microcosmic object has a certain size, therefore, $0<\rho(x)<1$. (4-3) the elimination variable *x*, matter waves Ψ (*x, k*) is mapped to the imaginary part *k* space. Get wave function *Φ*(*k*) of curvature *k* representation and matter field density distribution function η(*k*)

$$\int^{\infty}_{-\infty} A(x,k)dx=|\Phi(k)|^2=\eta(k) \tag{4-6}$$

Normalized representation

$$\int_{v} c\,\eta(k)\, dv=\int_{v} c|\Phi(k)|^2 dv=\int_{v}dv/v=1 \tag{4-7}$$

Field matter density η(*k*) and the probability density ρ(*x*) of appearance at position *x*, the relationship is as follows: high density of field matter, high probability, low density of field matter, uniform distribution of field matter density, uniform distribution of probability. Matter tells space-time how to have probabilistic attribute. Similarly, since the microcosmic object has a certain size, therefore, $0<\eta(k)<\infty$.

Special case, the field matter density is infinite, probability is equal to 1, is the mass point, the microcosmic object from the dual 4-dimensional space-time description back to 4-dimensional classical space-time description. In fact, the imaginary part *k* is the wave vector space of quantum field theory.

4.3. Fourier transform of *ψ*(*x*) and *Φ*(*k*)

$$\psi(x)\ =(2\pi|\hbar)^{(-1/2)}\int^{\infty}_{-\infty} \Phi(k)exp(ikx)d(\hbar k) \tag{4-8}$$

$$\Phi(k)\ =(2\pi\hbar)^{(-1/2)}\int^{\infty}_{-\infty} \Phi(x)exp(ikx)d(x) \tag{4-9}$$

Formula (4-8) and (4-9) are the transformation of representation of field matter density and probability density distribution. The field matter density is uniformly distributed, and the probability density is uniformly distributed; Where the density of field matter is large, the probability of microcosmic objects appear is high. Where the microcosmic object does not appear, the field matter density is zero and the probability density is zero. In quantum mechanics $\psi(x)$ and Φ (p) between the Fourier transform has a new physical meaning. Formula (4-8) and (4-9) are mathematical expressions that reveal the source of quantum probability physics. In two four dimensional spacetime, matter tells spacetime how to have probabilistic properties, and spacetime tells matter how to move probabilistically.

World famous historians of physics, philosopher of physics, professor Cao Tian-yu recently made clear that the dual 4 dimensional space-time of quantum mechanics:

- Along the tradition of Kaluza-Klein, Pauli also derives the tradition of gauge field theory, trying to derive the probabilistic features of quantum physics from more complex space-time structures (dual 4-dimensional space-time), thus providing a realistic interpretation of quantum physics.
- More complex spatio-temporal structures (dual 4-dimensional space-time) are constructed under the constraints of the probabilistic characteristics of quantum phenomena. In fact, the nature has yet to be confirmed, just as the reality of the four-dimensional space-time constructed by Minkowski is to be confirmed by the subsequent development of physics.
- Therefore, the emergence of quantum physics has made us have a clearer understanding of the richness and complexity of space-time structures, and the construction of dual 4-dimensional space-time has also made quantum physics have an objective ontological basis [22][23].

5.The universality of quantum mechanics and the fundamentally problems of quantum space-time

In dual 4-dimensional space-time quantum mechanics has no universality. Physical space-time is no good or bad. Each kind of space time can only describe physical phenomena at a certain cognitive level. As long as the cognitive level exists, the corresponding space-time exists. If it is used across boundaries, there will be cognitive conflicts, incomprehension and incoordination. Although Newton, special relativity, general relativity and quantum mechanics describe the physical phenomena at different cognitive levels, the space-time can be commensurable. In the change of cognitive level, one kind of space-time can evolve into another kind of space-time in a specific mode. For example, Newtonian space-time is the limiting mode of special relativity space-time; Special relativity space-time can be regarded as general relativity curved space-time local flat mode; Quantum mechanics dual 4 dimensional space-time is flat space-time, can also be regarded as general relativity curved space-time local flat mode. In addition, quantum mechanics is a dual 4-dimensional space-time. On the one hand, it is a complex extension of special relativity space-time; on the other hand, classical space-time is a limit modality in which the quantization of energy, momentum and microcosmic object structure tends to continuous change. It can be seen that between two space-time are transition to each other.

"Transition" does not mean that physical space-time can be used instead, but indicates that there is a commensurable between space-time. Since other space-time can be regarded as the local mode of gravitational curved space-time, gravitational space-time should be more fundamental. Quantum mechanics is not universality, and its space-time is only a local representation of gravitational space-time. The unified field theory in dual 4-dimensional space-time has new ideas.

6. Conclusion and discussion

- The physical model of quantum mechanics is the field matte sphere, and the particle model is not applicable;
- The spatial distribution and mass distribution of microcosmic objects are the origin of quantum probability;
- The space-time of describing microcosmic quantum phenomena is a dual 4-dimensional space-time. Matter tells space-time how to have probabilistic properties; Space-time tells matter how to behave probabilistically [22][23].

References

[1]. Zhang Yong-de, Quantum Vegetable Root Tan [M], Beijing: Tsinghua University Press, 2016, the third edition.15-54, 58-75..., 330-348.

[2]. M. Jammer, Philosophy of Quantum Mechanics [M], translated by Qin Ke-cheng, Beijing: The Commercial Press, 1989:70-78,52-55,67-99,328,598.

[3]. Dirac, Direction of Physics (M), translated by Zhang Yi-zong and Guo Ying-huan, Beijing: Science Press, 1981:9.

[4] Guo guang-can, Einstein's Ghost--The mystery of Quantum Entanglement [M] Beijing Institute of Technology Press (second edition), 2009.09.

[5]. Hong Ding-guo, Physical Realism (M), Beijing: The Commercial Press 2001:110-118.

[6].W. Heisenberg, Physics and Philosophy [M], translated by Fan Dain-nen, Beijing: The Commercial Press, 1981.

[7].Gao Shan, Quantum [M], Tsinghua University Press,2003, 180-191.

[8]. Rene Thom, Mutation Theory: Thoughts and Applications [M], translated by Zhou Zhong-liang, Shanghai: Shanghai Translation Publishing House, 1989:215-280, 625.

[9]. Sakata Shyoichi, Sakata Shyoichi Papers of Scientific Philosophy [M], translated by An du, Shanghai: Knowledge Press, 2001:140.

[10]. Yukawa Hideki, Elementary Particles [M], translated by Zhang Zhi-xian, Science Press, 1975:117-118, 120-130.

[11]. L. Smolin, the The trouble with physics [M], translated by li Yong, Changsha: Hunan Science and Technology Press,2008 p5_94.

[12]. Report of lewis, academic lecture hall, Research Center of Philosophy of Science and Technology, Shanxi University, web of philosophy of science and technology, 2018.10.21.

[13]. Zhao Guo-qiu, Quantum Mechanics Foundation in Dual 4-dimensional Space-Sime [M], Hubei Science and Technology Press, 2016.

[14].Ni Guang-jiong, li Hong-fang, Modern Physics [M], Shanghai: Shanghai Science and Technology Press,1979: P146~148.

[15]. Roger. Penrose, Road to Reality [M], translated by Wang Wen-hao, Changsha: Hunan Science and Technology Press, 2008:367-368.

[16]. V. F. Weiskoff, 20th Century Physics [M], translated by Yang Fu-jia et al., Beijing: Science Press, 1979:72-96.

[17].Zhao Guo-qiu, Interaction Principle and Three Approaches of Human Cognition of Nature, Journal of Wuhan University of Technology (arts edition) 2008, NO1, Copy Center of Renmin University of China, Philosophy of Science and Technology [J], B2 2008.NO6, reproduced in full.

[18].Zhao Guo-qiu, Describe Electron Spin and Spin Magnetic Moment in the Dual 4-dimensional Space-Time Quantum Mechanics, Modern Physics [J], 2014, No5.

[19] Zhao, Guo-qiu, (2014) Describe Quantum Mechanics in Dual 4 dimensional Complex Space-Time and the Ontological Basis of Wave Function. Journal of Modern Physics, 2014.5, 1684-1697.

[20].Zhao Guo-qiu, Searching for the Physical Mechanism of Superposition of Eigenstates, journal of Wuhan University of Technology (arts edition) [J], 2018NO3p1.

[21]. B. И rhett Nick, the Historical Narrative of Quantum Mechanics [M], translated by Huang Hong-quan, Peng Hao, Beijing: Science Press, 1979:66.

[22]. Zhao Guo-qiu, On the Construction Characteristics of Physical Space-Time, Shanxi International Symposium On the Basis of Quantum Mechanics (in English and Chinese), 2018.10.

[23] Zhao, Guo-qiu, (2016) Quantum Mechanics Foundation in Dual 4-dimensional Space-Time: The Space-Time Origins of Quantum Probability. Scientific Research Publishing (2016), Inc., Wuhan.