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The Matter Wave Is Space-Time Wave

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ABSTRACT

This paper aims to point out that a wave function is a description of a quantum spatiotemporal entanglement and the transformation between time and space. In any quantum mechanical representation, the real part of the wave function represents the space wave and the imaginary part represents the time wave, and they are the space-time itself. Time wave is not limited by space and dominates the nonlocality and integrity of a quantum. Matter wave is a four-dimensional space-time wave, and the basic unit of vacuum is a four-dimensional space-time element stationary relative to the observer. The essence of quantum measurement or interaction is that a conjugate condensation equivalent to that determined by inner product operation occurs between Space-time waves. Particle property is only the localization effect of quantum global collapse when quantum position measurement or equivalent interaction is made.

Keywords: Space-time wave; Space-time entanglement; Conjugate condensation；Four-dimensional space-time element.

INTRODUCTION

As we all know, the most basic postulate of quantum mechanics is the wave function postulate [1] the state of a micro particle system is completely described by a wave function $\psi(\boldsymbol{r},t)$, and the probability of finding particles in the distribution region $d\tau$of $\psi(\boldsymbol{r},t)$ is

$$dP = \psi^{*}\psi \, d\tau \tag{1}$$

Here $\psi *$ is the complex conjugate of ψ. This axiom implies that ψ is understood as the temporal and spatial weight distribution of particles in time and space. This is also the objective basis for probability interpretation. This probability is not a purely mathematical probability. We believe that quantum behavior has physical essence. Therefore, we express the axioms as follows: the probability of finding a particle in a region at any time is equivalent to the space-time weight of the particle in the region, and the probability amplitude is equivalent to the space-time amplitude, and the probability is an observable measurement based on space-time. In fact, under any representation, the quantum wave function is a complex number represented by imaginary time and real space, which is used to express a quantum as an entangled whole of time and space.

When expressed as a vector in the complex plane, the projection of the vector to the imaginary axis and real axis of the coordinate corresponds to the fluctuation intensity of time and space respectively, the mutual transformation of time and space makes it appear as a rotating wave vector on the complex plane. We will point out later that the time wave determines that a quantum is nonlocal. It is precisely because the quantum obeys the two characteristics of spatial nonlocality and the transformation between time and space represented by the phase angle of the wave function that we generally interpret the space-time wave as a probability wave. In classical mechanics, for macroscopic low-speed systems, time and space are relatively independent, but as a wave function that completely describes microscopic systems, it reveals to us that for quantum systems, even in the case of low-speed, time and space are closely related, the wave function is actually a description of the entanglement and mutual transformation of time waves and space waves. People must accept the fact that when it comes to quantum systems, even low-speed non relativistic systems, even if they generally do not involve the coordinate transformation between inertial systems, the four-dimensional characteristics of quantum systems are indispensable, and matter waves are four-dimensional space-time waves. Therefore, we believe that the real physical space is essentially a complex vector space. In a free state, even a single particle quantum system is just a propagating space-time wave. Quantum particle property is the integrity after conjugate condensation between spatiotemporal waves when quantum interacts or measures the system. Therefore, quantum wave and particle property are not established at the same time, The conjugate condensation between spatiotemporal waves also determines the rest mass and charge characteristics of matter particles. Based on the basic assumption that quantum is space-time wave, vacuum must be composed of countless four-dimensional space-time elements stationary relative to any observer as basic units. These space-time elements also constitute our space-time coordinates, through which matter expresses its physical properties.

QUANTUM SPACE-TIME WAVE AND SPACE-TIME ELEMENT AS VACUUM

First, let's examine the well-known one-dimensional plane wave of free particles

$$\psi = A(\cos\phi + i\sin\phi) = Ae^{i\phi} = Ae^{i(kx-\omega t)} = Ae^{\frac{i}{\hbar}(px-Et)} \quad (2)$$

As mentioned above, we directly express the wave function in the complex plane composed of $(x,\ ict)$, as shown in Fig.1, the propagating wave function is actually a complex vector (state vector) rotating counter clockwise in the complex plane. That is, the wave propagating at any point in space-time can be expressed as an arrow moving and rotating in four-dimensional space-time.

During unitary evolution, the length of the state vector ψrotating in the complex plane will remain unchanged, and its projection length to the spatial axis is

$$\Psi_R = A\cos[\ \ (px-Et)/\hbar] \quad (3)$$

which is the quantum space wave; The length of the projection to the ictaxis is

$$\psi_I = A\sin[(px-Et)] \quad (4)$$

which is the quantum time wave. Although time wave is closely entangled with space wave, it is different from the spatial attribute of space wave. It is in the time dimension, so it is not limited by space. It has spatial nonlocality.

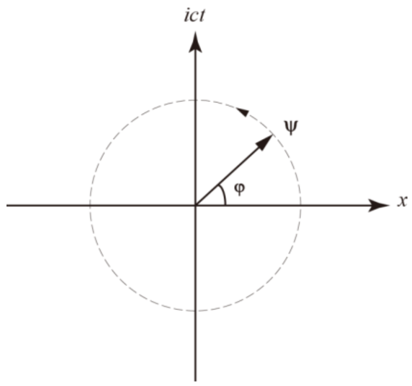

Fig. 1 Space-time wave representation of wave function

The quantity that can completely describe these characteristics of time wave is just the imaginary number in the wave function. The imaginary number $i$in time expresses at least the following physical properties of reality:

1. Time is always orthogonal to space;
2. Time always has the trend of transforming into space, that is, the rotation of space-time in the orthogonal plane, and the imaginary number i corresponds to the$90°$rotation of the plane. This property leads to the next property;
3. A quantum space is always transformed from its time, that is, there is a certain but non localized entanglement between space and time at any place of the matter wave.

The phase$\phi$of the wave function represents the state of mutual conversion of spatiotemporal wave amplitudes at a certain time, which is simply determined by the following equation,

$$\cot\phi = \frac{\psi_R}{\psi_I} = \frac{Space}{Time} \quad (5)$$

The corresponding phase velocity$u$is the velocity at which the time wave and the space wave are converted to each other, that is, the speed at which the wave completes one cycle in time (ψrotates one cycle on the complex plane), and it is also the speed at which the wave front with the same phase moves in space. We investigate the wavefront when the initial phase remains zero, so we have:

$$(px-Et)/\hbar = 0 \quad (6)$$

and

$$u = \frac{dx}{dt}\Big|_{d\phi/dt=0} = \omega/\kappa = E/P = \frac{1}{2}mv^2/mv = \frac{1}{2}v \quad (7)$$

Because the phase velocity u only expresses the change velocity of phase ϕ when ψ rotates in the complex plane, we point out that, unlike the classical plane wave, the phase velocity and propagation velocity of space-time wave are not necessarily equal, and the propagation velocity of space-time wave of a particle with rest mass is equal to the motion velocity of the particle.

Let's analyse the propagation characteristics of quantum time wave and space wave. Let t = 0, the initial phase is zero, and the wavefront is located at the coordinate origin, i.e. x = 0. At this time, the amplitude corresponding to the wavefront of time wave is the maximum, and the amplitude corresponding to the wavefront of space wave is 0. From the relativistic relationship, we have,

$$p_\mu dx_\mu/\hbar = -mc^2 d\tau/\hbar = -\frac{mc^2 dt}{\gamma\hbar} \approx -\frac{mc^2 dt}{\hbar} + \frac{1}{2\hbar} mv^2 dt \tag{8}$$

or

$$(\boldsymbol{p}\cdot\boldsymbol{dx} - Edt - mc^2 dt)/\hbar \approx (-mc^2 dt + Edt)/\hbar \tag{9}$$

Where

$$x_\mu = (\boldsymbol{x}, ict),\ p_\mu = (\boldsymbol{p}, i\frac{mc^2+E}{c}),\ \gamma = (1 - v^2/c^2)^{-1/2} \tag{10}$$

Therefore, in the first-order approximation, the phase of the wave front propagating from the coordinate origin will evolve according to the following relationship.

$$d\phi = \frac{\boldsymbol{p}\cdot\boldsymbol{dx} - Edt}{\hbar} = \frac{Edt}{\hbar} = \omega dt \tag{11}$$

or

$$d\phi = \boldsymbol{\kappa}\cdot\boldsymbol{dx} - \omega dt = \omega dt \tag{12}$$

The propagation velocity v_t of the wavefront is (simplified to one dimension):

$$v_t = dx/dt = 2\omega/\kappa = 2u = v \tag{13}$$

And the change speed of the phase corresponding to the wavefront with time:

$$d\phi/dt = \omega \tag{14}$$

which is the angular velocity of the wave vector when it rotates in the complex plane. From the above analysis, we can see that since the propagation velocity and phase velocity of the classical plane wave are equal, the phase of the wavefront always remains unchanged, but the phase of the wavefront of the space-time wave will change with time, and the sine or cosine waveform diagram is made at the velocity of v along the positive direction of the x-axis. The wavefront with the same phase.

For example, the peak or trough moves backward at the speed of $v/2$ relative to the wave front and propagates forward at the speed of $v/2$ relative to the stationary observer. For particles with zero rest mass, because $x_\mu p_\mu = 0$, it is easy to conclude that the phase velocity and propagation velocity of space-time wave are the speed of light c. In essence, only the place where the wave reaches is the place where the "particle" can appear, so the motion speed of the particle is essentially determined by the conversion speed of space-time, and the space-time conversion speed of light is a constant.

From the above analysis, we can see that when ψ is projected on the x axis and ict axis respectively, its time and space components are alternately transformed in space-time. Therefore, the process of forward propagation of space-time waves along the x axis is also the transformation process of quantum intrinsic space-time. From the Schrodinger equation that the wave function represented by (2) should satisfy, we get,

$$\left.\begin{aligned} \frac{\partial\psi_R}{\partial t} &= \frac{1}{\hbar}\hat{H}\psi_I \\ \frac{\partial\psi_I}{\partial t} &= -\frac{1}{\hbar}\hat{H}\psi_R \end{aligned}\right\} \tag{15}$$

which shows that the Hamiltonian of a quantum system determines the mutual transformation of time wave and space wave. At the same time, the above equation also expresses the entanglement relationship between time wave and space wave.

In fact, any fluctuation is the change of the value of one or some physical quantities of the system with time or space, while quantum fluctuation is the continuous change of time and space itself, and this is unitary evolution. At any space-time point within the quantum wave range, the time wave and space wave have the same maximum amplitude, and this relationship should remain unchanged when they are transformed between different inertial systems. Here, we use the space-time scale to discuss the space-time amplitude relationship of quantum. Let the maximum spatial amplitude of the quantum be Ξ and the maximum temporal amplitude be $c\Theta$. In a system at rest relative to particle, the quantum only corresponds to an amplitude proportional to the propertime, let it be equal, i.e. $c\Theta = c\Delta\tau$, in which case there is no spatial amplitude; The system with relative motion relative to particle produces spatial amplitudes (or spatial fluctuations) and accompanying time amplitudes (or time fluctuations).

The space-time waves of the quantum have alternating transformations. The maximum amplitude of space (the length of ψ coinciding with the space axis) will be proportional to the increment of space, similarly, we might as well let them be equal, that is, $\Xi = \Delta x$, because the maximum spatial amplitude and the maximum time amplitude (the length when ψ coincides with the time axis) are equal, i.e. $\Xi = c\Theta$, according to the relativistic relationship.

$$\Delta x^2 - c^2\Delta t^2 = -c^2\Delta\tau^2 \tag{16}$$

we get the maximum amplitude of quantum space-time wave, that is, the length of ψ is:

$$\Xi = c\Theta = \Delta x \equiv c\sqrt{\Delta t^2 - \Delta\tau^2} \tag{17}$$

The above equation still holds for particle with zero rest mass, where $\Delta\tau \equiv 0$. From this, we can also see that whether the rest mass of the quantum is zero or not, the relationship parameter between space-time conversion is the speed of light c. It should be pointed out that for an observer, the absolute amplitude of spatiotemporal wave has no physical effect, but the relative amplitude can show the physical effect. In quantum mechanics, the amplitude of spatiotemporal wave is described by the equivalent probability amplitude. In addition, the positive and negative of space-time amplitude is the polarity of space-time itself rather than the direction. Later, we will point out that the polarity of space-time leads to different polarization and expresses different space-time states. Generally, all wave vectors rotating in complex space (observer's space-time coordinates) constitute the state vector of Hilbert space. The representation transformation is the unitary transformation of the wave function, which is actually the rotation transformation of the state vector in the complex space. Obviously, for an observer, the complex space extended by the imaginary time axis and the real space axis is fixed. In addition, the space-time waves of dynamic variables under different representations at any time should have different amplitude values, and the aforementioned rotation transformation (phase change) will make the wave function just represent this value difference. Even under different representations, the imaginary part and real part of the wave function represent the space-time wave amplitude of the corresponding dynamic variable. In addition to the relativity of motion, quantum space-time waves in different coordinate systems have different forms. Even in the same inertial system, quantum will have different forms of space-time waves in different representations. In short, the imaginary part of any wave function represents the quantum time wave, and the real part represents the quantum space wave. As an example, let's examine the wave function $\varphi(\boldsymbol{p})$ of momentum representation by applying unitary transformation $\hat{U}$ to the wave function $\psi(\boldsymbol{r})$ of coordinate representation.

$$\hat{U}\Psi(\boldsymbol{r}) = \frac{1}{(2\pi\hbar)^{3/2}}\int \Psi(\boldsymbol{r})\, exp(-i\,\boldsymbol{P}\cdot\boldsymbol{r}/\hbar)d\boldsymbol{r} = \varphi(\boldsymbol{p}) \tag{18}$$

Let $\psi(\boldsymbol{r}) = Ae^{i\phi}$, then the above equation is

$$\varphi(\boldsymbol{p}) = \frac{A}{(2\pi\hbar)^{3/2}}\int exp[\,i(\phi - \boldsymbol{P}\cdot\boldsymbol{r}/\hbar)]d\boldsymbol{r} \tag{19}$$

As mentioned above, the wave function in momentum representation only changes the phase of the wave function in coordinate representation, and the rotation of the basis vector in complex space corresponds to the change of the argument of the wave function. In short, the real part of the material wave expressed in wave function or probability amplitude is space itself, and its imaginary part is time itself. Various representations are different expressions of space-time waves, and the regular conjugate quantities of these representations express the phase of space-time conversion. This also shows that space-time shows relativity not only in gravitational field and relative motion, but also in different physical representations. This also shows that quantum space-time is not absolute, it has the dual characteristics of objectivity and uncertainty.

It should be pointed out here that although the quantum time wave amplitude can take a negative value, the time coordinate of the observer is defined on the basis of time interval and is positive definite and continuous. For example, the left side of the Schrodinger equation is the differential of the wave function to the coordinate time, and the time is positive definite. We will point out later that the space-time coordinates of the observer are determined by the vacuum composed of countless space-time elements. Quantum space-time waves can be expressed as waves propagating along a straight line like plane waves, but there are rotating spatiotemporal waves, such as the eigenfunction of angular momentum operator $\hat{L}z$.

$$\varphi_m(\phi) = \frac{1}{\sqrt{2\pi}}e^{im\phi} \qquad (m = 0, \pm 1, \pm 2, \dots) \tag{20}$$

This means that the spatiotemporal amplitude of the spatial angle ϕ propagating around the z-axis at any time is

$$\psi_I = \frac{1}{\sqrt{2\pi}}sin(m\phi) \quad , \quad \psi_R = \frac{1}{\sqrt{2\pi}}cos(m\phi) \tag{21}$$

Here, we can also see that due to the existence of time wave, quantum angular momentum is essentially different from classical angular momentum. Quantum angular momentum describes the rotation of wave rather than the rotation of some matter.

An interesting example is the comparison of the spin waves of photons and electrons. We know that the spin of a photon is $\hbar$, its spin wave is related to the phase factor in the form of $e^{i\varphi}$, and the phase ϕ of the spin space-time wave in the complex plane is equal to the spatial angular rotation φ. For an electron with spin $\hbar/2$, the spin wave is related to the factor in the form of $e^{\pm i\varphi/2}$, the relationship between the phase ϕ of the spin space-time wave in the complex plane and the spatial angular φ rotation is $\phi = \varphi/2$, that is, one cycle of the phase change of the spatiotemporal wave corresponds to two cycles of the spin wave in space. It is easy to conclude that the spin space-time wave rotates one cycle in the complex plane, which corresponds to a spin with angular momentum$\hbar$,therefore, the relationship between the spin quantum number $m_s$and the spin wave phase ϕ and the space angle φ turned when the wave rotates and propagates in space is,

$$m_s = \phi/\varphi \tag{22}$$

The spin angular momentum is determined by the quantum number m_s satisfying the above relationship, which is independent of the speed of space-time wave rotation.

Another interesting phenomenon is the free electron plane wave solution given by Dirac equation. The positive energy solution (electron) contains phase factor.

$$exp[\, i(\mathbf{k}\cdot\mathbf{r} - Et/\hbar)] \tag{23}$$

That is, the electron wave function ψ_{-e} rotates counterclockwise in the complex plane like the ordinary wave function. The phase factor of negative energy solution (anti electron) is

$$exp[\, i(\mathbf{k}\cdot\mathbf{r} + Et/\hbar)] \tag{24}$$

If it is opposite to the direction of motion of the electron, that is, the momentum is opposite, the phase factor becomes,

$$exp[-i(\boldsymbol{k}\cdot\boldsymbol{r} - Et/\hbar)] \tag{25}$$

The rotation direction of the wave function ψ_{+e} of the anti electron in the complex plane is opposite to that of the electron wave function. If we define the behavior of the electron spatiotemporal wave in the complex plane as positive rotation, the anti electron is an anti rotating spatiotemporal wave. This situation suggests that if space-time is regarded as the most basic property of quantum, the antimatter state should be replaced by a positive definite observable time inversion state of energy or mass.

Space-time mutual transformation is the most basic property of space-time or material world. Whether it is a state with pure space property or a state with pure time property, we must express it as an evolution factor in the form of $e^{i\phi}$. they always correspond to the entanglement and transformation of space wave represented by real number and time wave represented by imaginary number, and participate in the interaction in this form. After interpreting the matter wave as a space-time wave, the matter wave becomes a real wave in space-time, then the medium transmitting the wave must also be real, and this reality has the characteristics of space-time itself. We must imagine the vacuum as the following form: the universe is filled with a large number of countable four-dimensional space-time elements that are relatively stationary for each inertial observer. They constitute a more basic spatiotemporal basis than elementary particles. Each spatiotemporal element is a spatiotemporal vortex rotating on the complex plane as shown in Figure 1.

In fact, in space-time without matter, the action amount of gravitational field can be taken as [2].

$$S_G = \frac{c^3}{16\pi G}\int R\sqrt{-g}\, d^4x = \frac{c^4}{16\pi G}\int R\sqrt{-g}\, dVdt \tag{26}$$

where G is the gravitational constant and R is the scalar curvature. Considering that the three-dimensional space of space-time element is a volume element dV, the above equation can be simplified to an integral of only time. At the same time, considering that a space-time element is stationary relative to any observer and therefore has no kinetic energy, the Lagrangian and Hamiltonian of a space-time element are,

$$L_G = \frac{c^4 R\sqrt{-g}}{16\pi G}\ ,\ H = -L_G \tag{27}$$

Therefore, the Schrodinger equation that a space-time element should satisfy is,

$$i\hbar\frac{\partial}{\partial t}\psi_0 = -\frac{c^4 R\sqrt{-g}}{16\pi G}\psi_0 \tag{28}$$

Thus, the wave function form of a space-time element is

$$\psi_0 = \Lambda\, exp(\frac{ic^4}{16\pi G\hbar}\int R\sqrt{-g}\, dt) \tag{29}$$

It can be seen from the above equation that the evolution factor of space-time element is completely determined by the curvature of space-time. It is a time state with only time evolution factor but no spatial evolution factor. Therefore, it evolves only along the time axis at a fixed spatial position, and it will not propagate (move) in space. Equation (29) will maintain the relativistic form for observers in any reference frame, Space-time elements are static relative to observers in any frame of reference. These static four-dimensional space-time elements fill the whole universe and form a quantized ether. Of course, this kind of stillness is relative. If a stationary observer can mark a space-time element, and a moving observer sees that the former observer propagates on his marked space-time element in the form of waves, The state of space-time elements corresponding to different observers corresponds to the representation of equation (29) in different coordinates. The movement of matter will change its space-time curvature.

So, what is the physical essence of space-time elements? Here we briefly point out that the space-time element in the vacuum is the time wave of the quantum system dominated by the Hamiltonian. The time wave with only one dimension always has the property of entanglement, so that entanglement will be established between all space-time elements. The entangled time combination is locally transformed into space to form matter waves. Matter is actually the result of the evolution of time entanglement between space-time elements, Therefore, on the contrary, the movement and distribution of matter determine the distribution of time waves on each space-time element and gravity at the same time. From the previous discussion, we know that the time wave in the material wave is nonlocal without space restriction. When the quantum fluctuates in local space and makes space-time transformation (unitary evolution), in fact, their time wave comes from the interior of all space-time elements in the universe. Part of these time waves are transformed into space waves locally, which forms space-time entangled material waves locally. The space wave determines the localization of the quantum, while the nonlocal entanglement of the time wave determines the integrity of the quantum. Equation (15) describes this spatiotemporal entanglement determined by Hamiltonian. The time amplitude of material wave is the superposition of the time amplitude of entanglement of all spatiotemporal elements. Later analysis will point out that this time amplitude should also include the static energy part of the quantum system, that is, the total energy of the system represents the time entanglement (amplitude) intensity of the system for all spatiotemporal elements. According to the law of gravity, we can infer that the contribution of space-time elements to a quantum's time wave amplitude is inversely proportional to the square of distance. Therefore, the vast majority of a quantum's time wave amplitude comes from the space-time elements near the quantum. When considering gravity, the total wave function needs to be the phase factor of the original wave function multiplied by equation (29), that is, gravity enters the quantum Hamiltonian in the form of potential energy. Due to the conservation of energy, the increase or decrease of quantum potential energy must correspond to the corresponding increase or decrease of its kinetic energy, such as the red shift or blue shift of light line in the gravitational field. When the wave propagates from one space-time element to another, the space-time bending difference between the space-time elements makes it behave as the difference of gravitational potential energy, resulting in the change of quantum kinetic energy, The corresponding momentum is what we usually mean by gravity. Like local material waves, equation (29) shows that the spatiotemporal evolution of spatiotemporal elements is still continuous, so even if spatiotemporal itself is quantized, it still maintains continuity. A four-dimensional space-time point is replaced by a four-dimensional space-time element, so the space-time evolution of a quantum system somewhere in space at any time becomes the space-time evolution state of the space-time element.

In this way, each four-dimensional space-time element not only acts as a four-dimensional medium, but also acts as a four-dimensional space-time background - four-dimensional coordinates. For ease of description, if we regard the gravitational effect of matter as the core of space-time element, then the local material motion or wave propagation is only the space-time transformation superimposed on its surface.

As an objective reality carrying quantum time waves, the four-dimensional space-time element fundamentally negates the possibility of the existence of nihilistic space-time in the universe. The entanglement effect produced by any substance spreads over all space-time elements, no matter how weak but not zero. Therefore, the gravity and inertia of a specific substance or energy can be uniformly described by the states of all space-time elements in the universe, Gravity and inertia are the same object - the time wave of a substance distributed in the space-time element. It can be seen from our previous discussion of anti-electrons that the effect of negative energy substances on space-time elements is opposite to that of positive energy substances. Suppose there is a large amount of antimatter somewhere or accelerate antimatter to close to the speed of light. It can be seen from equation (29) that on the same space-time element, the rotation direction of the space-time wave that produces gravitational effect on the complex plane (space-time plane) is opposite to that of normal energy matter. The time-space waves of the two rotation directions are superimposed in the same space-time element.

When the phase meets the complex conjugate condition. These two waves will be transformed from superposition into conjugate condensation and produce repulsive force. We can also see that positive and negative energies cannot be added or subtracted directly. They should obey the relativistic synthesis law. The specific expression satisfying this law is that the negative energy state is replaced by the time inversion state of the positive energy state, which will never offset each other on the same space-time element. Either they overlap each other or they conjugate condense, which makes the energy conservation strictly observed. In short, antimatter leads to the reverse bending of nearby space-time. In addition to forming a repulsive force with the space-time (gravitational potential) affected by normal energy matter, antimatter also exerts a reverse influence on the space-time element occupied by normal energy matter, resulting in the reduction of the inertia of normal energy matter in a local range, which is the effect caused by the reverse rotation of space-time wave in the same space-time element.

As a matter with local space waves, if there are mutually opposite rotations on the surface of the same space-time element, it will lead to the annihilation of positive and negative matter. From the above analysis, we can see that with the help of space-time element, time wave and space wave are entangled and correspond one by one, which equivalently expresses the one-to-one correspondence between matter or material field and gravitational distribution state. Then we can also think that the gravitational distribution state determines the state of matter or material field, and gravity and matter are different forms of the same objective object, The former is the time wave of matter, while the latter is the local space wave.Next, we briefly discuss the matter wave propagating on the space-time element in a figurative manner. If we use the action quantity S to represent the matter wave.

$$\psi = Ae^{iS/\hbar} \tag{30}$$

Then according to the principle of least action: $\delta S = 0$, it can also be expressed as the minimum principle of matter wave phase: $\delta\phi = 0$. According to our previous discussion, the phase is a description of the speed of the space-time mutual conversion of matter waves. The phase angle corresponding to the completion of a cycle of space-time conversion is 2π, that is,$S/\hbar = 2\pi$, or $S = h$, which indicates that a quantum completes a space-time conversion on a space-time element, which corresponds to a unit of action h, so a space-time element can also be regarded as an action quantum. Therefore, we can say that the minimum action principle is also the fastest principle of space-time conversion: in the process of matter wave propagating from one space-time element to another, the phase change is always as small as possible, that is, the wave propagation selects the fastest path of space-time conversion. The movement of matter is actually the propagation of matter waves, and it is also the transformation of time and space. The upper limit of this transformation speed is the speed of light.

Now, with the help of the assumption of space-time element, we make a phenomenological discussion on the propagation of space-time wave. Let's first look at the matter wave with non-zero rest mass. Imagine that an observer in a static state observes the propagation of a series of waves at a fixed point in space. Since a space-time element replaces a point in the traditional sense, it is replaced by observing the propagation of a space-time element. Let the space of the space-time element be Δx and the time be Δt, and let the propagation velocity of the wave be$v$. obviously, $v = \Delta x/\Delta t$, a series of waves must propagate on a finite number of n space-time elements, so the wavelength is $\lambda = n\Delta x$ and the period is $T = n\Delta t$. We have pointed out that the phase velocity of the space-time wave of the material with rest mass is $v/2$, so the phase velocity of its space-time wave on a space-time element is

$$u = v/2 = \Delta x/2\Delta t = \frac{\lambda/n}{2T/n} = \frac{\omega/2}{\kappa} \tag{31}$$

This equation shows that the space-time wave of matter with static mass propagates only half a cycle on one spatiotemporal element and transmits to the next spatiotemporal element, that is, the spatiotemporal element of matter with rest mass acts as a $\hbar\omega/2$ harmonic oscillator and transmits the wave with frequency ω. For a substance with zero rest mass, the phase velocity in the above equation is equal to the speed of light. We have,

$$u = c = \Delta x/\Delta t = \frac{\lambda/n}{T/n} = \frac{\omega}{\kappa} \tag{32}$$

The above equation shows that the space-time wave of matter with zero rest mass completes a whole cycle of spatiotemporal transformation on a space-time element. Through the above analysis, we can imagine that the general image of the propagation of matter waves on four-dimensional space-time elements is: a series of waves are superimposed on several space-time elements for space-time rotation, that is, rotating on the complex plane of a group of space-time elements at the same time, the space-time waves with rest mass only rotate for half a cycle in the space of this group of space-time elements, and the space-time waves without rest mass rotate for one cycle, The phase is continuously transmitted to the next group of space-time elements, and the whole column of waves represents a particle as a whole. For a fermion with a rest mass, its spin wave can be understood as a group of space-time waves rotating on several space-time elements. Each of them rotates around the space of the space-time element for one week, rotates around the complex plane for half a week, then transfers to the next space-time element, rotates around the space of the latter space-time element for one week, and completes the second half of the rotation of the complex plane. In this way, it rotates two cycles in space and completes one cycle in the complex plane, so the fermion is a semi-integer spin.

Using the wave function expressed by the action S in the form of equation (30), we can concisely understand the relationship between the space-time element as the quantization of space-time and the gravitational field. Note that the three-dimensional space of a space-time element is a volume element dV, and equation (26) will degenerate into only time integration for a space-time element. Therefore, in a vacuum with no matter but only gravity, the wave function of a space-time element is:

$$\psi = \Lambda e^{iS_G/\hbar} = \Lambda\, exp(\frac{ic^4}{16\pi G\hbar}\int R\sqrt{-g}\,dt) \tag{33}$$

This is the same as equation (29) derived from Schrodinger equation. According to the principle of the fastest space-time conversion we pointed out, that is, the variation of gravitational action is zero ($\delta S_G = 0$) which will lead to the Einstein field equation in vacuum; In a space-time element with other fields, the action S_M of all other fields and the corresponding Lagrange density L_M should be considered. The wave function of the corresponding space-time element is

$$\psi = \Lambda e^{i(S_G+S_M)/\hbar} = \Lambda\, exp\left[\frac{i}{\hbar}\int (L_G + L_M)\sqrt{-g}\,dt\right] \tag{34}$$

Similarly, according to the principle of the fastest space-time conversion, take the variation of the action quantity $\delta(S_G + S_M) = 0$, and the complete Einstein field equation will be derived. Obviously, if only the action of electromagnetic field is considered on a space-time element, the electromagnetic field equation can be derived according to the same principle, which is similar to other quantum fields. The above equation shows that a space-time element containing gravity and other material fields still remains in the form of time waves, that is, it is stationary relative to any observer, and the quantum fluctuations on the space-time element represent all quantum fields.

From equation (15), it is easy to see that the absolute value of the change rate of time wave and space wave with time is proportional to the amplitude of space-time wave. Combined with the fact that quantum obeys the fastest principle of space-time conversion, we can draw a conclusion: a quantum wave of unitary evolution always propagates to the place with the largest amplitude of space-time, that is, it always propagates to the direction with the strongest entanglement of space-time.

The space-time element with the largest space-time curvature has the lowest potential energy and the largest time amplitude, so the material particles always move towards the space-time element with the largest space-time curvature, which also obeys the principle of the lowest energy. In order to be logically self-consistent, it is necessary for us to make a simple analysis on why the general plane wave function does not contain the static energy part. According to the theory of relativity, the energy of a free particle is

$$E = \sqrt{p^2c^2 + m^2c^4} \tag{35}$$

At low speed, the first order is taken as $E = mc^2 + \frac{1}{2}mv^2$. For the plane wave case, it is easy to verify that the phase factor $e^{-imc^2t/\hbar}$ in the wave function can be eliminated from both ends of the Schrodinger equation. If there is a static energy term in the wave function, the Hamiltonian operator representing the total energy of the system should include the static energy term, and let the wave function containing static energy be

$$\psi' = e^{-imc^2t/\hbar}\psi \tag{36}$$

The Schrodinger equation is extended to

$$i\hbar\frac{\partial}{\partial t}e^{-imc^2t/\hbar}\psi = (mc^2 - \frac{\hbar^2}{2m}\nabla^2)e^{-imc^2t/\hbar}\psi \tag{37}$$

We will soon find that the static energy term at both ends of the above equation will be automatically eliminated and degenerated into the Schrodinger equation without static energy term. In the literature of quantum mechanics, the plane wave solution of the free electron Dirac equation contains the stationary energy term.

If we express the total energy term of the solution as the sum of the stationary energy term and the kinetic energy term, and substitute the solution into the Dirac equation of each component, it is not difficult to find that the stationary energy term can also be eliminated from both ends of the equation. In this case, Dirac equation will degenerate to

$$i\hbar\frac{\partial}{\partial t}\chi = c\boldsymbol{\alpha}\cdot\hat{\boldsymbol{p}}\chi \tag{38}$$

Here χ is the wave function without the stationary energy term. The static energy term is actually the sum of the time entanglement amplitudes of the correlated quantum static energy part and all space-time elements. It is a time state that evolves only along the time axis, so it does not have spatial propagation characteristics and will not form coherence in space. For example, for the wave passing through the double slit, if the wave passing through the slit 1 and the slit 2 takes into account the static energy term, the wave passing through the double slit can be expressed as

$$\psi = e^{-imc^2t/\hbar}(\psi_1 + \psi_2) \tag{39}$$

$$|\psi|^2 = |\psi_1 + \psi_2|^2 \tag{40}$$

That is, the factor of the static energy term does not have the interference ability and can be ignored. The time wave of either static energy or kinetic energy is regarded as the nonlocal time entanglement of the space-time element in the whole space. This entanglement makes the quantum maintain the nonlocal integrity. When the physical interaction occurs, its space position will follow the position of the space wave corresponding to the kinetic energy.

QUANTUM CONJUGATE CONDENSATION AND MEASUREMENT

We know that the fluctuations of several quantum states can be linearly superimposed to form superimposed States, but the difference we will discuss below is the quantum effect after a quantum state ψ meets the conjugate stateψ^* and interacts. Since we have interpreted the matter wave as the space-time of physical reality, the interaction between quanta will be replaced by the interaction of space-time. When the spatial positions of the propagation of two quantum states conjugated to each other overlap, if the amplitude of the time wave is opposite - the polarity of time is opposite, and the mutual conjugation is symmetrical about the space axis, resulting in the transformation of the time wave into the space state. Due to the conservation of quantum space-time, the physical state after their interaction is the collapse of the quantum wave to the space form; On the other hand, if the two quantum states conjugated to each other have the opposite amplitude of space wave - the opposite polarity of space, and the conjugation is symmetrical about the time axis, which leads to the transformation of space wave into time state, and the physical state after their interaction is the collapse of quantum wave to time form. We call this special case the conjugate condensation of quantum states, and its mathematical expression is the well-known scalar product (ψ, ψ).

Therefore, the scalar product of the wave function is a description of the interaction between quantum states. Each observable measurement corresponds to the conjugate condensation of the observable eigenstate. In this paper, we propose the second axiom: the scalar product of the state vector is equivalent to the conjugate condensation between space-time waves. As an observable quantity, probability is the result of the conjugate condensation of space-time waves. For example, the probability of particles appearing somewhere in space is the measurement of the position of space-time waves, and the probability of particles appearing in a certain momentum range is the measurement of the momentum of space-time waves. This means that the observable quantum state can always be conjugated with the state of the measuring device. The measurement is equivalent to preparing the wave function conjugated with the measured subsystem. The measurement cannot be understood as the self-action of a single quantum. The conjugate condensation between quantum states is a continuously changing physical process, because the evolution of this process with time satisfies the well-known relationship as follows

$$i\hbar\frac{\partial}{\partial t}(\psi * \psi) = -\frac{\hbar^2}{2m}\nabla \bullet (\psi * \nabla\psi - \psi\nabla\psi *) \tag{41}$$

The condensation process is accompanied by the flow of space-time. The well-known law of probability conservation can be derived from the integration of the above equation. Probability conservation is the conservation of space-time that we point out here. When the quantum is conjugated and condensed, the time wave entangled with the space wave is not limited by space, and the space-time wave is conserved in a non-localized way, which makes the wave dispersed in the whole space collapse to a certain position in space, showing the integrity of quantum or the particle nature of quantum. For a single particle, the space-time wave amplitude (spatiotemporal weight) at any time satisfies the following conservation law.

$$\frac{d\|\psi\|}{dt} = \frac{d}{dt}\int_{-\infty}^{\infty}\psi * \psi dV = \frac{d}{dt}\int_{-\infty}^{\infty}(\psi_R^2 + \psi_I^2)dV = 0 \tag{42}$$

Quantum has the integrity shown by ignoring space distance, so that the conservation of mode $\|\psi\|$ satisfies a non-localized conservation, such as entangled quantum pairs far away from space, quantum dispersed to the whole space in the double slit experiment, etc. the fundamental reason for these characteristics is that the quantum contains time waves that are not limited by space, and they are always entangled with space waves. Because the conjugate condensation process between quantum states is very complex, most condensation results are difficult to be intuitively expressed in the form of inner product, such as the measurement of electron spin wave under non-uniform magnetic field, the movement of quantum state in potential field, and the penetration of quantum potential barrier and potential well. These processes involve the relationship between quantum and field.

Quantum field theory points out that all fields are also quantum states, so the above process is also the conjugate condensation process of quantum states.

Let's discuss quantum conjugate condensation intuitively. In Fig. 2, in the complex plane formed by the x-axis and ict -axis,$\psi$and its conjugate state ψ^* at any time are represented as two arrows in a certain direction.

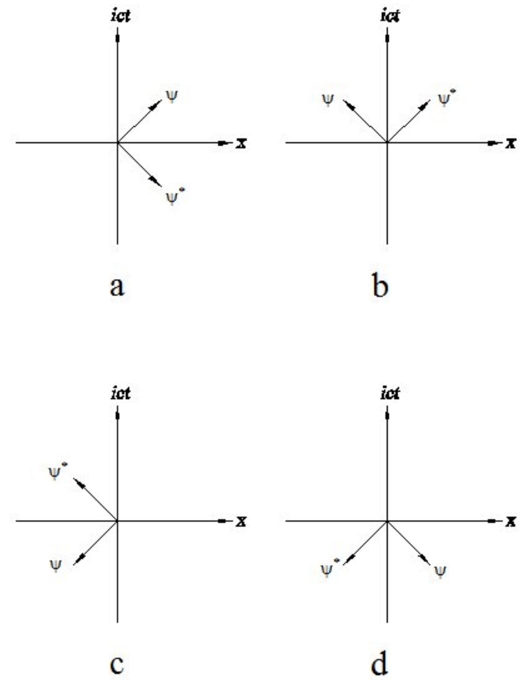

Fig. 2 Four forms of ψ and conjugate state ψ^*, which are also four possibilities of space-time collapse.

The quantum state in Fig (2a) corresponds to a conjugate state symmetrically along the spatial axis. Obviously, this conjugate state represents a space-time wave with the same spatial polarity but the opposite time polarity of the former. Since the multiplication of the complex number is actually the multiplication of the amplitudes and the combination of their phase angles by a rotation, that is, the phase angles are eliminated and the amplitudes are multiplied, the inner product in the case of Fig (2a) is to rotate them to coincide and merge with the$x$ -axis in the positive direction.

Assuming that the wave function is normalized, the inner product is simply expressed as $(\psi, \psi) \to 1 \times 1 = 1$; Rotate the state vector of Fig (2a) by $\pi/2$, that is, when both ψ and ψ^* are multiplied by i or $e^{i\pi/2}$, the conjugate relationship shown in Fig (2b) is obtained. At this time, their temporal polarity is the same and their spatial polarity is opposite. Their inner product is to rotate both $i\psi$ and $i\psi^*$ to coincide and merge with the positive direction of the ict -axis. The inner product is simply expressed as: $(-i\psi, i\psi) \to i \times i = -1$; Rotate the conjugate relation of Fig (2a) by π, that is, when both ψ and ψ^* are multiplied by i^2 or $e^{i\pi}$, the conjugate relation symmetrically along the negative x-axis shown in Fig (2c) is obtained. At this time, their spatial polarity is the same and their temporal polarity is opposite. Their inner product is to rotate $(-\psi)$ and $(-\psi^*)$ to coincide and merge with the negative x-axis. The inner product is simply expressed as $(-\psi, -\psi) \rightarrow (-1) \times (-1) = 1$; Rotate the conjugate relation of Fig. 2a by$3\pi/2$, that is, when ψ and ψ^* are multiplied by i^3, the conjugate relation symmetrically along the negative direction of the ictaxis shown in Fig (2d) is obtained. At this time, their temporal polarity is the same and their spatial polarity is opposite. Their inner product is to rotate $(-i\psi)$ and $(-i\psi^*)$ to coincide and merge with the negative direction of the ictaxis. The inner product is simply expressed as, $(i\psi, -i\psi) \rightarrow (-i) \times (-i) = -1$.

We note that in the conjugate condensation from collapse to time shown in Fig (2b) and Fig (2d), the inner product result is negative, which means that the two conjugated quanta are reduced by one after merging. In quantum mechanics, this physical process is described by the action of annihilation operator. When spin is not considered, the conjugate state of a spatiotemporal wave is its time inversion state, so we can imagine the two states of conjugate condensation as backward propagating States, but the evolution of States is a periodic phenomenon, so there is a relativistic Doppler effect for a moving observer. We will point out later that this effect will be reflected in the matter particles after conjugate condensation.

In quantum mechanics, there is a mutually orthogonal state, that is, the inner product of two wave functions is zero. In our spatiotemporal interpretation theory, they can be simply expressed as states that cannot undergo conjugate condensation. For the cases shown in Fig. 2a and Fig. 2c, the spatiotemporal waves undergo conjugate condensation in the form of collapse to space. For example, the position and momentum of particles are measured, a phase factor$e^{i\phi}$ in the wave function of particles is eliminated, and a pair of canonical conjugate variables$x$and$p$ hat jointly determine the phase angle are changed, the whole wave position collapses to somewhere in space, accompanied by the momentum exchange of the two interacting quanta. The process of conjugate condensation is also suitable for expressing the motion of quantum field, because the field is a spatiotemporal wave distributed on spatiotemporal elements. Because the conjugate condensation collapsed into space will not have the generation and annihilation of particles, and the time wave is still related to the integrity of each particle, with the change of observable physical quantities, quantum will de condense and enter unitary evolution again. Obviously, the process of de condensing should be the inverse process of conjugate condensation. Fig (2b) and Fig (2d) show that the conjugate condensation collapsed into time makes the inner product of the wave function negative, that is, there is the so-called negative probability, and there is a case of non-conservation of the number of particles. Therefore, the condensation collapsed into time corresponds to the generation or annihilation of particles, the change of time wave dominating quantum integrity or particle property, and the structural change of matter.

This collapse also makes the rest mass and energy of particles have positive and negative values due to different time polarity after collapse, and the negative energy state is the time inversion state of the positive energy state. The phenomenon that twoγ photons condense to produce a pair of positrons and positrons can be taken as an example of the condensation of space-time waves towards time. Photons without rest mass condense to produce particles with rest mass, which shows that the space-time waves form mass and form an inertial coordinate system after collapsing towards time. Equations (23) and (25) express these two results.

To sum up, the measurement of quantum conjugated mechanical quantities is the conjugated condensation of the quantum system corresponding to the space-time wave of the measured sub and the measuring device. When the observable measurement is obtained, it will be accompanied by the exchange of the observable measurement and cause the phase angle of the quantity determined in the wave function to change. If the two waves are conjugated to each other and the time wave amplitude is opposite, the wave will collapse into a spatial form, The quantum shows spatial localization, that is, it collapses to a certain point in space. Because there is no particle production or annihilation in this case, the quantum will eventually decoherence to obtain new mechanical quantities and re unitary evolution; If the amplitude of the space wave at each point in space is opposite and condenses, the wave collapses into a time form with the generation or annihilation of particles.

So, we can generally say that space-time is the most essential attribute of quantum. The essence of any operation or operator action on quantum is the interaction of space-time waves between quantum. The quantum system after this interaction is still space-time waves, and the mechanical quantity is the description of the effect of the physical event of wave conjugate condensation. For example, the measurement of momentum or position causes the phase determined by the conjugate momentum and coordinates to change. Depending on the coordinate quadrant (see Figure 2) where the phase angle is located during the conjugate condensation of wave function, the phase angle will eventually change from any ϕ value to 0 or π. According to the uncertainty principle of common position and momentum, we have,

$$\Delta\phi = \Delta x \Delta p/\hbar \geq 1/2 \tag{43}$$

Accordingly, for high-energy particles, conjugate condensation of collapse time may occur, and the particle structure changes, as shown in c and d of Fig. 2. This type of condensation makes the inner product of the wave vector take a negative value, that is, corresponding to the negative probability, corresponding to the generation or annihilation of particles. The phase of the quantum wave changes from any value to $\pi/2$ or $3\pi/2$. According to the uncertainty principle of time and energy.

$$\Delta\phi = \Delta E \Delta t/\hbar \geq 1/2 \quad (44)$$

We must admit that the details of the conjugated condensation of quantum states are not completely clear at present. According to the theory of quantum mechanics, the change of the conjugated condensation process of the two quantum states with time will be determined by equation (42), and the condensation result will be determined by the inner product (ψ, ψ) of the wave functions that are conjugated to each other. The definitions of Hermite operator (operator postulate) and measurement (mean postulate) in quantum mechanics are also expressed by the conjugation of wave functions. Considering that the matter wave is distributed on numerous space-time elements, this is consistent with the quantum field theory that regards the quantum system as various quantum fields. The interpretation of quantum space-time inevitably requires the spatiotemporal of quantum fields. The time wave of quantum conjugate condensation (wave function collapse) dominates the nonlocal integrity of the quantum. When measuring the quantum, we always get a whole quantum. When measuring a general state in Hilbert space, it always collapses into an eigenstate rather than several non-integral states according to the classical mathematical projection rules. A typical example is the spin wave of the electron, no matter which direction we measure it, the spin will appear as a whole, and the result we measure is always the entire spin angular momentum of the electron. Another famous example is the measurement of quantum entangled states in quantum mechanics, for example, if the paired electrons and antielectrons A and B are in the following spin entangled states:

$$|\psi>_{AB} = \frac{1}{\sqrt{2}} \left(|\uparrow>_A |\downarrow>_B - |\downarrow>_A |\uparrow>_B \right) = \frac{1}{\sqrt{2}} [\psi_{R(AB)} + i\psi_{I(AB)}] \quad (45)$$

here $\psi_{R(AB)}$ and $\psi_{I(AB)}$ are space and time waves of spin entangled states, respectively. According to our previous spatiotemporal interpretation of the wave function, the wave function is the entanglement of time waves and space waves. The above equation shows that even if the space waves of electrons A and B are far away from each other, their common time waves are not limited by space and will still be nonlocally entangled with them. If the measured result $\sigma_z^A = +1$ is obtained, it can be inferred that $\sigma_z^B = -1$, i.e

$$A <\uparrow |\psi>_{AB} = \frac{1}{\sqrt{2}} |\downarrow>_B \quad (46)$$

this corresponds to the conjugated condensation of state $A <\uparrow|$ and state $|\psi>_{AB}$.

The measurement is actually the interaction between magnetic field and spin. The entangled state collapses nonlocally through the time wave. In fact, the measurement of electron spin by the Stern-Gerlach device can be expressed by the effect of Pauli matrix describing the interaction between magnetic field and spin on the spin wave. In the σ_z representation, we express the eigenstate of S_z as

$$\chi_{z+} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \quad \chi_{z-} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

As an example, let's look at the following effects of Pauli matrix on spin wave

$$\sigma_y \chi_{z+} = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} = i\chi_{z-} \quad (47)$$

From the above equation, we can see that σ_y can change the upward spin to the downward spin. In addition, the real and imaginary parts of the spin wave are exchanged, that is, the time wave and the space wave are exchanged. To sum up, we can draw the following conclusions:

The essence of quantum state corresponding to the representation of observable mechanical quantities is space-time waves. The observable physical quantities do not have objective reality and certainty before measurement, but are only the results or physical effects of the conjugate condensation (collapse) of space-time waves. Once we measure various observable mechanical quantities defined, it means that we have arranged the conjugate condensation modes of different types of waves, Obviously, there is no obvious distinction between measurement and interaction. The so-called measurement is just a physical interaction set by people;

The time wave of the quantum system is a wave originating from the space-time element in the time dimension, but it is always accompanied and converted with the space wave locally. Therefore, at any time, the quantum nonlocal time wave and the localized space wave have definite entanglement. The time wave determines the integrity of the quantum and the space wave determines the localization of the quantum. It is inferred that if the observable quantity of the quantum system is constant in all inertial systems, for example, the rest mass is the time wave from all space-time elements, and the charge is the time wave (electric field) from a large number of local space-time elements, which ignores the spatial distance and maintains the integrity, the spatial localization of the quantum will be determined by the space wave associated with it.

As we have pointed out earlier, although the wave function of a free particle does not contain the rest energy in the time dimension, but only the kinetic energy part causes the space-time wave, its spatial localization can be determined by the space wave associated with it.

Therefore, the space-time wave and the rest mass maintain integrity at any spatial position. When interacting or observing (measuring), the spatial position of wave collapse must also be the position where a particle appears as a whole. When space-time waves propagate, the most probable path is selected according to the principle of the fastest transformation of space-time. Therefore, when we observe the motion of elementary particles on a large scale, we will get a classical concept of orbit.

QUANTUM FIELD MECHANISM BASED ON SPACE-TIME ELEMENT

The basic interaction can be described as a quantum field. After the matter wave is interpreted as space-time, all quantum fields are endowed with the essence of space-time and have different representations in space-time elements. We have assumed that the vacuum is full of space-time elements. Unlike the classical ether, the four-dimensional space-time elements are static relative to any inertial observer. At the same time, we have to revise our traditional concept of space-time to: the space-time interval or the so-called wide ductility of space-time - the scale and clock reading are the properties of space-time. They are the results of observable measurement or interaction rather than space-time itself. Space-time itself is the quantum space-time amplitude at any time. From subatomic structures to macroscopic objects, the reason why we can always obtain the experience of space-time scale is that various physical interactions actually take place under the seemingly stable surface, that is, the quantum conjugate condensation that we pointed out in this paper. The quantum conjugate interaction can collapse the wave and localize it. We know that in relativity, space-time distance is defined as the four-dimensional interval between two successive events. According to our point of view in this paper, the occurrence of events corresponds to the conjugate condensation between quantum, and the occurrence of conjugate condensation is determined by the amplitude of quantum, and the amplitude of quantum is space-time itself. Different from isotropic three-dimensional space, time itself must be represented by an imaginary number. We must treat this as the reality of matter. The time interval as part of the four-dimensional interval is regarded as an observable physical quantity, so it is a real number. Like all quanta, the space-time element has no definite space-time scale, and the space-time scale is replaced by the amplitude of space-time transformation.

On average, we can also imagine a single space-time element as a four-dimensional space-time volume unit, whose four-dimensional volume is an invariant:$\sqrt{|g|}\Delta^4 x = \sqrt{|g'|}\Delta^4 x'$. in the case of strong gravity, the spatial scale will be extremely reduced and crowded into time. On the contrary, its spatial volume will expand and the time factor will be shortened. Equation (34) shows that all physical properties of a space-time element are determined by the distribution of all matter, but the space-time element is localized (determined spatial position) because it does not propagate. Its spatial part forms a volume element of a three-dimensional vacuum. The spatial components of all space-time elements determine the spatial scale of the universe. The time components of each space-time element come from the entanglement of all other space-time elements in the universe with the volume element. In this way, they form the base of four-dimensional space-time. As we pointed out earlier, matter is the evolution result of entanglement between space-time elements, which cannot be cut off or shielded. Therefore, after the formation of the universe, these space-time elements can neither disappear nor create. Therefore, the total number of these space-time elements in the universe is conserved, because the static mass of a particle is expressed by its entanglement or time amplitude of all space-time elements in the universe, Therefore, the conservation of space-time elements is also the premise that identical particles have the same static mass and other basic parameters.

According to equation (34), matter and field are expressed as the sum of time waves entangled by a space-time element and all other space-time elements. For the sake of visual description, we may make the following distinction: gravity expresses the internal structure or internal space-time flow of a four-dimensional volume unit, while other matter or matter fields of different forms, such as electromagnetic field, are space-time flow on the surface of a four-dimensional volume unit: Four-dimensional rotating space-time waves. Gravitational effect is the polarization of the interior of the space-time element, while other substances or fields are the polarization of the surface of the space-time element; On the other hand, because static is relative, an observer with relative motion relative to matter will observe the additional effect on the space-time element caused by the motion of matter. We call this effect the spatial polarization of the space-time element, and the corresponding state is called the spatial state. For example, the magnetic field generated by the moving charge, because the mutual transformation of space-time is the inherent attribute of space-time, The expression of magnetic field as a spatial state is still a spatiotemporal evolution factor. We believe that the basic symmetry of space-time corresponds to the basic degrees of freedom of space-time or space-time patterns, such as space-time rotation, space-time translation, etc., which derive quantum particles. As an electromagnetic interaction derived from rotational degrees of freedom, its space-time mode is expressed by four-dimensional electromagnetic potential, vector potential$\boldsymbol{A}$ is its space wave, and standard potential$i\ \varphi/c$ is its time wave. The four-dimensional rotation or four-dimensional flow of electromagnetic space-time wave is known as four-dimensional curl.

$$(curl\ A)_{\mu\nu} = F_{\mu\nu} = \frac{\partial A_\nu}{\partial x_\mu} - \frac{\partial A_\mu}{\partial x_\nu} \tag{48}$$

which represents the electromagnetic field, so the four-dimensional potential can be regarded as the definition of space-time itself, and the vortex of the four-dimensional potential is the electric field and magnetic field, When the operation is applied to space-time, it will still maintain the characteristics of space-time. Therefore, the electromagnetic field can be regarded as the definition of electromagnetic space-time wave from the perspective of force, the two have some equivalence. For example,E_x is a vortex in the plane stretched by the ict axis and the x axis, forming a localized spatiotemporal wave.

In the traditional sense, the irrotational nature of the electrostatic field means that there is no rotation in space. However, when time is understood realistically, the electric field is a spatiotemporal vortex, and its spatial characteristics make it local and chiral. Pure space vortex (magnetic field) and time-space combined vortex (electric field) are components of four-dimensional vortex. As a differential form, the above equation defines the minimum space-time structure, so we think that the electromagnetic field can be expressed as a space-time wave rotating around a four-dimensional surface of a single space-time element. For example, we understand operator $\nabla\times$ as a vortex around a space-time element surface. Equation (48) shows that the representation mode of electromagnetic space-time corresponds to the generator of Lorentz group, which is the space-time mode expressed by the degrees of freedom allowed by space-time symmetry. Physically, there is no absolute rotation of space-time, therefore, the gauge invariance of electromagnetic potential is the expression of relativity of electromagnetic space-time, so gauge symmetry is also a kind of space-time symmetry. In quantum mechanics, the magnetic field acting on a moving charge is described by $exp(\,i\frac{e}{\hbar}\oint_c \boldsymbol{A}\cdot d\boldsymbol{l})$, which is the evolution factor of a space wave, where C is any closed path. In the case of magnetic shielding, the vector potential $\boldsymbol{A}$ (space wave) flows from one space-time element to another space-time element in a large range to form a circulation; In the absence of magnetic shielding, if C can be reduced to a minimal path around a single space-time element (a point in the traditional sense), then $\oint \boldsymbol{A}\cdot d\boldsymbol{l}=\boldsymbol{B}\cdot\Delta\boldsymbol{S}$, then the local magnetic field is expressed. When the vector potential $\boldsymbol{A}$ rotates around a single space-time element to form a spatial vortex, the vortices attract each other in the same direction, otherwise they repel each other. The drag force formed between the vortices is magnetic force. The drag force of the vortices causes countless space-time elements to form closed spatial polarization, that is, closed magnetic force lines. Therefore, the magnetic field is the spatial polarization of charged substances on the surface of space-time elements. Overall, the electric field and magnetic field in the four-dimensional space-time are the performance of the same objective object under different coordinate transformations. The electric field is the time polarization or time entanglement of the charged substance on the surface of the space-time element and determines the integrity of the quantum particle. It forms a local charged substance together with the space wave or space polarization.

The electron and anti-electron formed by photon collision is an electromagnetic phenomenon of four-dimensional vortex conjugation condensation with backward propagation and conjugation. A pair of photons before conjugation condensation are regarded as four-dimensional vortices with both space and space-time vortices. After conjugation condensation, space collapses to time and forms positive and negative masses of charges due to different time polarities. The orientation (chiral) of space-time vortices after collapse forms charges of different polarities, therefore, the gradient of scalar potential should be understood as the vortex on the time and space tectonic plane. Consider an observer who has relative motion with the charge. In this observer's view, the reference frame of the static charge is the light source. There is a relativistic Doppler effect in the two columns of light waves propagating backward in space before the conjugate condensation. Therefore, the charge after the conjugate condensation will not be just static. The charge will be represented as a propagating space-time wave and accompanied by space-time conversion. For example, the first term of the relationship $\boldsymbol{E}=-\frac{\partial}{\partial t}\boldsymbol{A}-\nabla\varphi$ is the motion effect of space into time, this also makes a moving charge transverse electric field enhanced. In addition, consider the following relationships:

$$\frac{\partial \boldsymbol{E}}{\partial t}=\nabla\times\boldsymbol{B} \qquad \frac{\partial}{\partial t}(\nabla\times\boldsymbol{A})=\frac{\partial \boldsymbol{B}}{\partial t}=-\nabla\times\boldsymbol{E} \tag{49}$$

The first equation shows that the time of motion effect is transformed into space, so that the vortex on the space-time surface changes with time, that is, the electric field changes with time to form a rotating magnetic field; The first equation shows that the time of motion effect is transformed into space, so that the vortex on the space-time surface changes with time, that is, the electric field changes with time to form a rotating magnetic field; The second equation shows that a space vortex on the space-time element can form an electric field vortex, namely a rotating electric field, when it changes with time. The rotating electromagnetic field is a space-time wave propagating in rotation, which is called spin. In a word, the motion effect is manifested in the mutual transformation of space-time. One increases while the other decreases. After multiplying the imaginary number i in front of the electric field $\boldsymbol{E}$, it has the same phase as the magnetic field $\boldsymbol{B}$. the phase represents the transformation state of space-time, which is the same as the matter wave discussed earlier. If we express the electromagnetic space-time wave in the following vector form

$$\boldsymbol{\Psi}=\boldsymbol{B}+i\boldsymbol{E}/c \tag{50}$$

Considering $x_4=ict, j_4=ic\rho$, Maxwell's equation is expressed as

$$\left.\begin{aligned}\nabla\cdot\boldsymbol{\psi}&=\mu_0\, j_4\\ \nabla\times\boldsymbol{\psi}&=\mu_0\mathbf{J}+\frac{\partial\boldsymbol{\psi}}{\partial x_4}\end{aligned}\right\} \tag{51}$$

This intuitively describes the electromagnetic vortex localized on a space-time element. When the four-dimensional vortex photon conjugation condenses into a charge, the magnetic field of the space vortex collapses to the electric field of the space-time vortex. The temporality of the electric field dominates the integrity of the charged quantum particles, while the spatiality is manifested as the chiral of the electric field. If the time and space surface vortices that form positive and negative charges are defined as right-handed and left-handed respectively. We can use this feature to understand the phenomenon of repulsion and attraction between electrostatic charges graphically: the time polarization of electrostatic charges to space-time elements is equivalent to the virtual vortices excited by charges outward to these space-time elements, that is, virtual photons in field theory. The direction of these vortices is the same as the direction of vortices generated when charges move towards these space-time elements. For example, the vortex direction generated by the positive charge can be expressed as the right hand clenching the fist and pointing the thumb outward from the positive charge, and the direction of the four fingers is the vortex direction. Imagine that there is a negative charge nearby, and use the left hand to express the vortex direction in the same way. It is not difficult for us to find that the rotation directions of the left and right hands with positive and negative charges will be the same. As we mentioned earlier, the same rotation direction means mutual attraction; On the contrary, if two charges are the same, they rotate in the opposite direction when they are close to each other, which shows that they are mutually exclusive. To sum up, the moving charged particles can be simply described as a cluster of four-dimensional vortices rotating on the space-time element and the intensity changes with time. The electromagnetic field intensity and spin are the representations of their different characteristics. Electromagnetic field, as a kind of space-time wave with rotation, makes the surface of space-time elements spin (four-dimensional) polarization. The rotation of virtual photon pairs after conjugate condensation (collapse) determines the polarity of charge. The right rotation is positive charge, and the left rotation is negative charge; When the time characteristic collapses in the positive direction, it becomes an ordinary charged substance, while when the time characteristic collapses in the negative direction, it is a charged antimatter, such as an anti-electron; The electromagnetic vortex on each space-time element is a rotating space-time wave, and its rotation direction determines the spin direction of the electron. Therefore, spatiotemporal waves with spatiotemporal vortex structures such as electromagnetic fields have three characteristics at the same time during conjugate condensation: the left and right directions of spatiotemporal waves determine the positive and negative of charge, while the positive and negative directions of time determine the positive and negative of mass, and the direction of electromagnetic field determines the direction of spin. At the same time, the integrity or quantum of these three characteristics of a charged particle is determined by the time wave of the corresponding representation. Therefore, when the electromagnetic potential is understood as space-time, the symmetry of charge becomes the reflection symmetry of four-dimensional space-time, and the symmetry of positive and negative mass becomes the symmetry of positive and negative time or the symmetry of time inversion. This expression is equivalent to the definition of quantum field theory, because conjugation in quantum field theory means that the imaginary part of the wave function changes the sign, which is actually changing the polarity of the time wave. It should be emphasized that a single photon, electron and other electromagnetic substances cannot be seen as a point particle, that is, a single charged substance is not a phenomenon that only occurs on a single space-time element. The most obvious is a static charge whose electrostatic field is distributed in a large space. At this time, we should understand this as: a cluster of space-time elements are time polarized. Due to the relativity of space-time, for the motion observer, a moving charge is a rotating space-time wave formed by the time and space polarization of a large number of space-time elements. At this time, a charge is represented as a wave propagating on a cluster of space-time elements, and its integrity or quantum is dominated by the local time wave.

The above discussion is about the electromagnetic material composed of vortices in the synthetic plane of time and space. Now let's consider a material structure derived from the conjugate condensation of pure space vortices, which may help us to have a pictorial understanding of neutrinos. Suppose that two pure space vortices with opposite spatial rotation direction and opposite propagation direction, such as $\pm\nabla\times\boldsymbol{A}$, occur conjugate condensation on a space-time element. Like all conjugate condensation, because collapse requires space-time conservation, their pure space is transformed into time. The time polarity after collapse determines that they are matter particles or antimatter particles. Relative to the static observer of the particle, it is a time state with rest mass. However, for a relatively moving observer, considering that the vortex is a periodic phenomenon and Doppler effect, the two pure space waves of their conjugate condensation do not just offset each other. The intensity of the vortex towards the observer is greater than the intensity of the vortex away from the observer, so the particle is no longer a time state but a space vortex in a certain direction, Assuming that the relative motion direction of a particle is left-handed, that is, the left thumb points to the motion direction, and the spatial vortex direction is the direction of the other four fingers, this left-handed feature will remain unchanged due to the relative motion effect; Correspondingly, if the time in the collapse direction is negative, that is, it collapses into antimatter, which is equivalent to the space-time wave conjugation of the former, and the time inversion is equivalent to the spatially reversed wave, that is, the left rotation becomes right rotation and becomes an antiparticle. The pure empty vortex has no charge characteristics, and if the vortex condenses on one or a few space-time elements, it is very difficult for such matter particles to interact with other matter.

The intrinsic complex four-dimensional space-time characteristics of quantum, which constitutes the material world, inspire us to believe that the symmetry represented by Lorentz group is also a basic symmetry satisfied by quantum space-time. Each symmetry provides a degree of freedom for quantum space-time. The generators of the group correspond to the corresponding space-time patterns. The continuous transformation of four-dimensional space-time allows us to understand different quantum states as different expressions of space-time. By combining these properties with the space-time elements, we may have a pictorial understanding of quantum field theory. Scalar matter corresponding to spatial translation invariance is represented as a scalar field in the space-time elements; The space-time elements of spinor matter corresponding to rotation invariance are represented as spinor fields. Accordingly, this means that the force in particle physics is the exchange of particles, which can be understood as the exchange of space-time.

At the end of this section, we will discuss some interesting results when we treat matter waves as spatiotemporal waves. First of all, we imagine a toy universe consisting of only two space-time elements marked 1 and 2. At the time of the birth of the universe, there is no space but only time. Therefore, these two space-time elements are in the time state of ψ_1 and ψ_2 respectively. The fact that time only occupies one dimension and is not limited by space leads to the entanglement of the two space-time elements. The space-time element marked 1 contains its own time factor ψ_{11} and the time factor ψ_{21} of space-time element 2, The corresponding space-time element 2 contains the time factor ψ_{12} of space-time element 1, so the two space-time elements in the time state can be expressed as the direct product of entanglement:

$$\psi_1 = \psi_{11}\psi_{21}\ , \quad \psi_2 = \psi_{22}\psi_{12} \tag{52}$$

Then the wave function of the toy universe is the entangled state of two space-time elements.

$$\psi = c_1\psi_1 + c_2\psi_2 \tag{53}$$

where c_1 and c_2 are constants. We have pointed out that space-time always obeys the law of mutual transformation, so both temporal and spatial states must be expressed as an evolution factor. Therefore, $\psi_1$and ψ_2 in equation (52) are wave functions entangled by local time waves and space waves. Back to the real universe, if the above two space-time elements are far enough away to ignore the gravitational interaction, $\psi_1$and ψ_2 can be approximated as pure states to express the local quantum of matter. Equation (53) shows that although the initial time of the universe is a separated time state, time always has the property of entanglement, which causes the universe to behave as an entangled whole, which must correspond to a total space-time wave function. Modern cosmological observations show that the expansion of the spatial scale of the universe is accelerating, which means that the spatial scale of each space-time element is getting larger. As we know from our previous discussion, this also means that the spatial scale of a constant four-dimensional line element or four-dimensional volume element is getting larger. According to this evolution mechanism of the universe, we make the following assumptions: since a quantum is expressed as a space-time transformation in the way shown in Figure 1, Extending this to the whole universe means that all phenomena in the universe are the evolution of space-time itself. If the universe is taken as an isolated whole, it should logically follow the same space-time transformation law, that is, the universe as a whole also corresponds to a wave function and will evolve in the same way as shown in figure 1! The universe originates from the time axis. As shown in Figure 1, when the phase angle of the space-time wave determined by all the matter in the universe is $\pi/2$, the universe is composed of a huge but finite number of entangled time states. At this time, the universe has no space attribute, which corresponds to a singularity without space size. The number of time states is the number of space-time elements we pointed out, and they are the total number of sub states of the universe. The polarities of these time states point to the positive axis of time, indicating that they are all normal matter States, that is, the universe is represented by a state dominated by positive matter. Briefly, when the phase angles in equation (34) are$\pi/2$ respectively, that is, when

$$\frac{1}{\hbar}\int(L_G + L_M)\sqrt{-g}\,dt = \pm\pi/2 \tag{54}$$

all space-time elements of the universe are time states. They are singularities without space size and correspond to positive and negative energy (matter) states respectively. As the phase angle of all quantum states increases, the time state begins to evolve to the space state, the universe begins to have space, the space suddenly increases and expands, and the matter is far away from each other. From equation (53) in the above example, we know that the matter (matter wave) is only the result of the entanglement between space-time elements, and the total quantum number of the universe, that is, the total number of space-time elements, remains unchanged in this process; When the phase angle is $\pi/2$ to π, the universe will always be in an expanding state, which is exactly the universe we currently observe. When the phase angle is π, it will become a pure space state; At the evolution stage of the phase angle from$\pi$to $3\pi/2$, the universe will always be in a contracting state and once again become a pure time state when the phase angle is $3\pi/2$, and the polarity of all quanta will evolve to point to the negative time axis. At this time, the universe is dominated by antimatter; Similarly, when the phase of cosmic space-time wave determined by matter is π or 2π , all space-time elements evolve into pure space state, and the phase of cosmic total space-time wave is different from$\pi$and$2\pi$and collapses to different spatial polarity. The characteristic that space and time are always changing each other is the ultimate attribute of space and time. If this judgment is true, the ratio of the current space scale to the time scale of our universe is the cotangent of the phase angle of the cosmic wave function represented by equation (3). This functional relationship should be verified by observing the retrograde speed of celestial bodies at different distances. So, this means that the expansion of the universe is caused by the mutual transformation of cosmic space-time, rather than the generally assumed dark energy.

According to our space-time wave theory, matter with a rest mass should be formed by quantum conjugate condensation with a rest mass of zero. The time polarity after condensation determines that they are ordinary matter or antimatter, which also implies that all particles with antimatter have a rest mass. As we have pointed out earlier, each basic symmetry of space-time corresponds to a degree of freedom of space-time. Corresponding to the two modes of rotation and translation of space-time, matter can be divided into electromagnetic matter with vortex space-time structure and scalar matter without vortex. Electromagnetic matter with vortex can be regarded as the conjugate condensation of virtual photons in vortex space-time, Scalar matter with a static mass can only be formed by the conjugate condensation of scalar space-time waves with a static mass of zero. The conjugate condensation of scalar space-time waves can form a stable material structure under the extreme conditions of the formation of the universe and the early stage. If such scalar matter exists in the universe, they may be candidates for dark matter. In a word, interpreting space-time as the final background of all appearances may inspire us to make a new investigation on some unresolved physical problems.

DISCUSSION

In this paper, we replace the statistical interpretation of the wave function with a more extensive space-time interpretation, which also means redefining the concept of quantum: a quantum is the entanglement relationship between the time wave and the space wave in a nonlocal way. The nonlocality of the time wave determines the integrity of a quantum. One of the basic properties of quantum space-time is the endless mutual transformation. It is this basic property that forms the so-called first driving force of the universe. Quantum is space-time, all other observable physical quantities, such as energy, momentum, angular momentum, spin, charge, mass, space-time scale, space-time position, including probability, are the physical effects produced by quantum measurement or quantum interaction or the properties of space-time itself. The essence of measurement or interaction can be described by the conjugate condensation of space-time waves (the inner product of wave vectors), Even if the wave function collapses during measurement or interaction, the quantum system evolves with a certain law, which essentially obeys the physical law rather than a pure mathematical probability. Since the basic properties of matter are derived from quantum or the space-time waves we pointed out, various fields including gravity are no exception. For example, the electromagnetic field or potential should be formed by the space-time waves corresponding to the electromagnetic structure, and the virtual particles correspond to the matter waves on the space-time element. Different types of matter waves determine the conjugate condensation of different types of space-time waves, resulting in different types of interactions and corresponding observability, that is, only space-time waves with the same structure can conjugate and interact, so different types of fields exchange different types of field quanta, which may help us to understand quantum field theory more vividly and establish a unified world picture in the future. We also hope that the spatiotemporal interpretation and in-depth study of matter waves can make several independent basic postulates of quantum mechanics become interrelated and more concise.

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