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The Spatiotemporal Interpretation of Wave Function May Solve the Mystery of Quantum Entanglement

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ABSTRACT

In this paper, the wave function is interpreted as space-time: under any representation, the real part of the wave function represents space and the imaginary part represents time. A wave function represents the quantum entanglement (correlation) between time and space. The unitary evolution process is the mutual transformation of space-time. The imaginary time indicates that it can entangle with space in a non localized way and dominate the integrity (unification) of a quantum, which is the essence of quantum entanglement.

Keywords: Spatiotemporal interpretation of wave function; Space-time entanglement; Quantum entanglement.

INTRODUCTION

We know that a wave function is generally expressed as a complex number composed of real and imaginary parts or a vector on the complex plane, and a unitary evolution wave function can be expressed as a vector rotating on the complex plane. For example, one-dimensional plane waves can be simply represented in the following Figure (1).

In quantum field theory, Feynman diagram vividly depicts the evolution and interaction of these rotating vectors in space-time. According to the statistical interpretation of wave function, wave function represents the probability amplitude of quantum particles, which inevitably means that its basic mechanism is statistical. If the state vector identity of Hilbert space is mapped to Minkowski space, so that the real part of the wave function is mapped to the space $\boldsymbol{r}$-axis of Minkowski space, and the imaginary part is mapped to the time ict-axis of the imaginary number, then we can make a spatiotemporal interpretation of the wave function: under any representation, the real part of the wave function represents space and the imaginary part represents time, and a wave function represents the quantum entangled (correlated) between time and space. The unitary evolution process is the mutual transformation of space-time. The time of the imaginary number indicates that it can entangle with space in a non-localized way and dominate the integrity (normalization) of a quantum. Therefore, people no longer need to assume an implicit variable to dominate a quantum.

This interpretation turns the basic mechanism of quantum into a space-time background, which is physical, and the probability becomes the result of measurement or space-time interaction, which is only an observable measurement. Any representation transformation or coordinate transformation only rotates the state vector in space-time and will not change its space-time properties. Time is expressed as an imaginary number on ict-axis expresses at least the following properties [1].

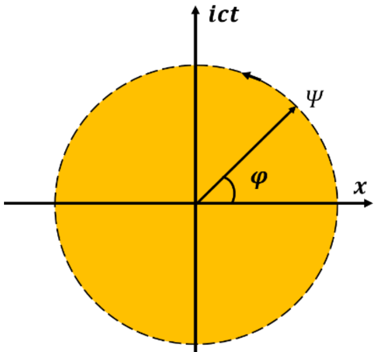

Fig 1.

1. Time and space are orthogonal; space wave has localization and time wave has nonlocality.

2. Time always has the trend of transforming into space, which corresponds to the rotation of the state vector on the space-time complex plane, and the imaginary number I corresponds to the 90° rotation of the complex plane. This property leads to the next property.

3. A quantum space is always transformed from its time, that is, the quantum space wave has deterministic nonlocal entanglement with the time wave at any place.

The spatiotemporal interpretation of wave function reveals that entanglement is a universal phenomenon in the quantum world. For example, a quantum that passes through a double slit still retains its integrity even if its space wave propagates along any path. For another example, the entangled states of A and B quantum pairs with spin entanglement can be uniformly expressed as a spatiotemporal entangled state.

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

Even if the space wave of the quantum pair propagates far away in space, the time wave that is not limited by space is still entangled with the quantum pair in a non-localized manner, unless the entanglement is cut off by measurement or interaction. The spatiotemporal interpretation of wave functions can give us a very intuitive understanding of some quantum phenomena. For example, spin waves can be understood as spatiotemporal waves rotating and propagating around space. The spin waves of fermions with 1/2 spin rotate and propagate around space for two weeks, and their spatiotemporal conversion is completed once. This is because the propagation speed of quantum waves is not equal to the spatiotemporal conversion speed (phase speed). It is easy to prove that the space-time wave propagation speed of a quantum with a motion speed of v is v and the phase speed is v/2; For another example, antimatter state can be understood as a time inversion state with negative time polarity, and quantum measurement or the interaction between quantum and field can be interpreted as the inner product between state vectors, etc.

In addition, the spatiotemporal interpretation of the wave function forces us to understand the universe as full of a huge number of four-dimensional space-time units. The total number of these space-time units is conserved and stationary relative to any observer (ensuring the law of invariance of the speed of light). Each space-time unit can be understood as a time wave without spatial transmission factors and represents the source of gravity or inertia of matter. The space-time wave of a space-time element containing the gravitational field action SG and the quantum field action SM can be expressed as [2].

$$\psi=\Lambda e^{i(S_G+S_M)/\hbar}=\Lambda\, exp\left[\frac{i}{\hbar}\int(L_G+L_M)\sqrt{-g}\,dt\right] \tag{2}$$

Obviously, according to the minimum action principle of quantum field or gravitational field and through variation, the corresponding field equation can be obtained. At this time, the minimum action principle is also equivalent to the fastest principle of space-time conversion. All kinds of symmetry of quantum field will have its source of space-time symmetry. The spatiotemporal interpretation of wave function attributes the accelerating expansion mechanism of the universe to the phenomenon of spatiotemporal transformation without the domination of dark energy. The transformation of time into space will inevitably lead to the expansion of space and the universe will be cyclic evolution. In a word, the spatiotemporal interpretation of wave function makes us understand quantum as space-time itself, and the concept of space-time we get from experience is actually space-time interval. Physically speaking, the space-time interval is the result of event or quantum interaction. The space-time coordinates based on this are naturally continuous and the time interval is a real number. Similar probability, space-time interval, momentum, energy, etc. are understood as the interaction of quantum space-time or the observable measurement of quantum measurement.

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