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RESEARCH ARTICLE

REALISM IN QUANTUM WAVE FUNCTION.

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Abstract
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Wave function, as both mathematical framework and conceptual framework involves objectivity and subjectivity, matter and consciousness, determinism and underdeterminism, locality and non-locality, and so on. Therefore, it becomes the hardcore of quantum theory, which should be significantly explored in the framework of philosophy. The realism of wave function has significant influence on the interpretation of quantum measurement, the development of quantum private communication, and the construction of quantum space, which in turn helps us to understand the realism of wave function further. In this paper, we discuss the realism of wave function and its future possible roads.

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Introduction:-

The realism of wave function has been the disputation all through the development of quantum mechanics. In 1924, De Broglie related the wave propagation to the motion of particles following corresponding law, which illustrated how to match a particle or a group of particles with the scalar waves in quantum system. In 1926, Erwin Schrödinger published four articles about the wave equation, which indicated that we needed to find a function ψ and ensured that its evolution involving the quadratic integral can be stable on the whole coordinate space. Therefore, ψ must be realistic everywhere, single-valued, finite, and second-derivative consecutive, which was called the mechanical field scalar. The wave function cannot be directly described in the general 3-dimensional space and is the function of the configuration space, instead of the real space. The quantization condition, according to Erwin Schrödinger, was clarified by the Schrödinger equation in solving the problem of hydrogen atom under specific physical conditions.

In 1926, Max Born, enlightened by Einstein's wave-particle duality, proposed the statistical interpretation of wave function [1, 2] and indicated that the wave in quantum field is not the ripple of realistic physical quantity, but the mathematical description for probabilistic distributions of particles. In the meantime, Weiner Heisenberg endowed the wave function with philosophical significance, i.e. the representation for some inclination to some thing. Subsequently, Albert Einstein proposed the statistical ensemble interpretation, while Erwin Schrödinger gave it to realistic interpretations and claimed that the wave function belongs to the scientific reality.

The scientific reality denotes the reality described in the theory of sciences, whose content lies in two levels. Firstly, It equates the theoretical entity and its framework described by the scientific theory, e.g. the astro-structure revealed by the astronomy, the atomic structure described by the atomic physics, as well as the theoretical entities such as electron, photon, gene, quark, and so on. Generally speaking, scientific reality includes the theoretical concepts and the properties of theoretical entity reflected by the connotation of proposition, such as the redshift in the general relativity. The entity and property correlate to each other by the relation, and the three factors form the bidirectional

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mechanism of limitation. In this paper, we, from the viewpoint of scientific reality, discuss the realism of wave function from three criterions, i.e. the observability, the causal effect, and the semantic criterion. Then we indicate the problems of realism of wave function and discuss the possible roads.

Wave Function Realism:-

The wave function itself cannot be observed directly and just can be indirectly controlled, and the information carried by wave function can be transmitted, which tells us that the wave function possesses the observability. The wave function is controllable and can transform the state of the quantum system from one to another within a limit time. Accordingly, the quantum system, although it satisfies the Heisenberg's uncertainty principle, is controllable, which illustrates that both wave function and operator have the reality.

According to the causal criterion, the entity is the reason for some observable phenomenon. Although the entity cannot be directly observed, we can claim its existence, if we can observe the causal prediction of the theory about the corresponding entity. Consequently, the wave function satisfies the causal criterion, because it obeys the Schrödinger equation. We can control the evolution of wave function, according to the evolutionary equation, by constructing the evolutionary operator. In the experiments of quantum mechanics, we can get the causal prediction for the wave function from all the quantum phenomena, e.g. the delayed-choice experiment.

From the semantic criterion, both the concepts and theories logically include the realistic entity and have the direct observable significance. The wave function can explain correctly the phenomena, which cannot be explained by the theories in the framework of classical physics. According to the Schrödinger equation and assuming some initial and boundary conditions, we can obtain the expression consistent with the experience, such as the energy level of hydrogen atom.

The wave function produces or forms due to the motion of particles. The "particle" and "wave" are two kinds of manifestations of matter, both of which have energy. Accordingly, probabilistic wave and matter wave can unify with each other. Furthermore, probability is subject to event, and the event has the material properties, the three of which forms the trinity. If we treat the wave function as mathematical tool, we potentially believe that the related physical interpretations, corresponding to the mathematical formula, describe the true properties of the unobservable entity. The mathematical formula, which have no any physical interpretations, are just abstract forms separated from the physical world and cannot be given experience explanation. So it has no any need to discuss such mathematical formula, and the mathematical formula used and discussed must be physically significant.

Therefore, the wave function realism actually represents a physical field consisting of the matter objects with reality. The physical field consists in the configuration space and is independent of the entity, whose properties are also independent of the distributions of matter in the space. The description for the physical field [3] needs to resort to the set of each point in the configuration space [4], which consists of two parts, the amplitude and the phase. Consequently, the wave function is the fundamental object and consists in the configuration space, which is the exact concept of "wave function realism". Because both the configuration space and the operators have infinite degrees of freedom, the wave function must be a high-dimensional field. In this sense, the wave function realism endows the entity of wave function in quantum mechanics with both ontological and epistemological statement.

Problems in Wave Function Realism:-

If the wave function is the high-dimensional field consisting in the high-dimensional configuration space, the problem is the realness of the high-dimensional field and the road to it, because of its distinct knowledge with the macro-objects in the ordinary 3-dimensional space.

It is considered that the macro-objects are the apports and have no realness, according to the mutation interpretation, which resulting from the lack of additional intrinsic structures, i.e. the form of Hamiltonian makes the 3-dimensional spatial structure to be the apport. Specifically speaking, both the Heisenberg representation and the Schrödinger representation are introduced in order to discuss the interactions, which relate to each other by the unitary transformation. Therefore, we can divide the interacting representation into two parts: the free system, without interactions, and the interactions reflecting the Hamiltonian, i.e. the interacting Hamiltonian. It is one of the functions in the Hamiltonian, i.e. the interaction between the potentials [3], that describes the ordinary 3-dimensional world. Accordingly, the quantum Hamiltonian makes the quantum world to present as 3-dimension, although it is just an apport.

It is assumed that the wave function evolves as one track, which plays a functional part in the universe filled with 3-dimensional particles. In the framework of mathematics, we compare the high-dimensional configuration space with 3-dimensional ordinary space and construct isomorphic correspondence, in order to make the two kinds of spaces to obey the same dynamical relation and causal relation. Then the high-dimensional space has the same function as that in 3-dimensional space, which can be perceived. The causal effects resulting from the dynamical evolution of wave function form the real particles consisting in the 3-dimensional space, despite of its deductive nature. These particles are theoretical entities and have realness, which can be perceived and observed and thus knowable. However, each observation for the entity can just show its one level and one perspective under corresponding condition, instead of its complete picture. We just can pave the road to the truth with the further development of its knowledge.

Roads of Wave Function Realism:-

Road to antirealism

It is claimed that all dimensions in the high-dimensional space are isotropic, and there is no priority in the noumenon for each dimension. The peaks of wave function circumfuse in some region of the configuration space, which contribute to the macro-objects. Different values of the peaks match with different classical descriptions [4]. That is to say, the macro-objects are reduced to peaks of wave function, which actually doesn't remove the high-dimensional configuration space. Therefore, there are two spaces in fact. The particles locate in the ordinary 3-dimensional space, while the wave function locates in the high-dimensional configuration space. Both wave function and high-dimensional space are pure mathematical tools, which are used to explain the tendentious characteristics of the N-particle system. However, the wave function and particles, according to the wave function antirealism, locate in different spaces, without any causal relation. As a consequence, there must be some kind of factor that relates them to each other, and thus how to correlate them becomes the problem. From the viewpoint of epistemology, it will move to the polyphyletism, if the high-dimensional space cannot be reduced to 3-dimensionsl ordinary one [5]. From the viewpoint of ontology [6], the high-dimensional space and 3-dimensional space obey the individual causality, which moves to the dualism and pluralistic determinism. If the wave function in high-dimensional space [7] has influence on the particles in the different space, it needs an intrinsic correlation between these two spaces, which finally leads to the dualism and the mystical teleology.

Road to quantum state realism

A logically self-consistent theory must give the experiments and phenomena in the field to consistent illustrations and provides new prediction to the best of its ability. Such criterion reveals both the consistency of causality between that in concepts and that in nature and the similarity between the theoretical picture and the reality, which also limits the consistency and similarity to the essential correlation of reality. If the theory is appropriate, its description for the observed entity must be true, by which we can derive the conclusion consistent with the observed phenomena.

In a quantum system consisting of N identical particles, we can change the phase of initial wave function and keep the amplitude unchanged, thus producing a new wave function. Then both of the functions describe the same quantum state, i.e. the wave functions just with different phases actually describe same state, and the differences resulting from the phase are unobservable. Accordingly, the correlation between wave function and quantum state is several-for-one. If we choose the Hilbert space and describe the quantum state as complex vector wave function, the different wave function, with different significance in physics, describes different quantum states. Therefore, the wave function and quantum state are one-to-one mapping, and thus the wave function realism equates the quantum state realism. If we choose new canonical momentum as the energy of the quantum system, the new canonical coordinate should be the conjugate quantity to the energy, which is called as time state and has the same dimension and different concept with the time of the system. The wave functions, with same amplitudes and different phases, have the same physical meaning and different mathematical forms, which describe the same quantum state. In this sense, the quantum state corresponds to a vector on the Hilbert space, instead of projection of the Hilbert space. Based on the quantum state realism, we can construct the space-time state [8], by relating the quantum state described by the wave function to the correlated space-time region, which opens up a route to the theory of quantum space-time, such as quantum field theory and quantum gravity.

Road to quantum field theory

As the product of a combination of special relativity and non-relativistic quantum mechanics, the number of all kinds of particles in the quantum theory of field [9, 10] is not constant, because each particle has corresponding antiparticle, with same mass and opposite charge. The transformations between particles and antiparticles reflect the generation and annihilation. The quantum theory of field in essence is a theory about multi-particles system, with changeable number of particles. It is the changeability of the number of particles that make us to interpret the wave function in non-relativistic quantum mechanics as high-dimensional field, and such problem disappears in the system with infinite degrees of freedom, which can be one of possible roads of wave function realism.

In the quantum theory of field, the quantum fields manifest as both quantum particles and quantum fields, which have two kinds of properties, the state-independent property, i.e. intrinsic property, such as inertial mass, charge, spin, etc. and the state-deterministic property, i.e. extrinsic property, such as the space and momentum. The transformation between quantum particle and quantum field reflects the uncertainty of extrinsic property, while the intrinsic property is specific and the change of particles with same intrinsic properties will not change the state of the system. Accordingly, the wave function, as one of the existence forms of quantum objects, has no longer permanent invariant, which can be generated, annihilated, and transformed. However, the quantum entity represented by the wave function can never be created and destroyed.

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