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On the Impossibility of Fater-than-Light Quantum Signals

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Abstract

This paper examines the history of Bell's inequality from EPR argument to Bell's papers, and the influence of Bell's inequality on the frontier exploration of quantum mechanics. It is found that Bell's inequality has some hidden assumptions that are different from EPR argument. Some scholars have led to the erroneous conclusion that quantum information exceeds the speed of light. Along Schrodinger's idea that the measurement process of the EPR experiment requires time, Karl Hess treated time as a time order parameter, and got a local hidden variable inequality that is different from Bell's inequality. Joy Christian extended the method of space-time geometry analysis of relativity to the localized geometry analysis of quantum states, and found that the reasoning of Bell's inequality does not meet the requirements of the completeness of EPR argument. The mainstream quantum gravity researches have made great progress, but there are many disagreements. According to Einstein's local realism, some new interpretations and new representations of quantum mechanics are given, which may open up new ideas for quantum gravity research.

Keywords

Quantum Information, Superluminal Propagation, Bell's Inequality

1. Introduction

In the history of the development of quantum mechanics, there are a Copenhagen School of matrix mechanics which was represented by Niels Bohr, Werner Heisenberg and Max Born, and some challenging wave mechanics schools represented by Albert Einstein, De Broglie and Erwin Schrodinger. The subsequent development of quantum mechanics mainly adopts the Schrodinger equation of wave schools in mathematics and physics, but its philosophical interpretation mainly follows the Copenhagen School's quantum probability interpretation, uncertainty relation and complementarity principle [1].

An important contest between Einstein and the Copenhagen school was EPR's argument in 1935. Einstein and his follows tried to prove that the two particles separated by each other didn't interact with each other, and the measurement of one of the particles should not affect the state of another particle. But when we measured the two particles independently, the determination of quantum state of one particle seemed to define the state of another particle in an instant. According to Einstein, quantum mechanics can't give the concealment mechanism of this effect, so it is incomplete [2].

Bohr believed that EPR argument ignores the failure of the law of conservation of momentum in quantum measurements, this avoids the possibility that quantum states of the two particles have instantaneous effects as Einstein said [3]. In the original dispute between Bohr and Einstein, there was no superluminal transmission problem of quantum information. In the 1950s, as David Bohm developed a theory of hidden variables of quantum potentials [4], people began to raise the question of whether there are local hidden variables in quantum state correlations mentioned by Einstein in the EPR argument, and quantum entanglements described by Schrodinger. David Bohm's non-local quantum potential theory can explain a large number of quantum mechanical problems, and poses a huge challenge to Copenhagen interpretation of quantum, but Einstein was not satisfied with this cheap explanation that violates the spirit of relativity. Bohm only admitted influences at-a-distance between quantum states and whole correlations, but he didn't believe that information can be transmitted beyond the light speed.

In 1964, John Bell proposed a set of inequalities on the theory of local hidden variables in 'On the Einstein-Podolsky-Rosen paradox', arguing that the prediction of quantum mechanics must violate these inequalities: "*In a theory in which parameters are added to quantum mechanics to determine the results of individual measurements, without changing the statistical predictions, there must be a mechanism whereby the setting of one measuring device can influence the reading of another instrument, however remote. Moreover, the signal involved must propagate instantaneously, so that such a theory could not be Lorentz invariant." [*5] Therefore, there is no any local hidden variable theory that can completely reproduce all experimental predictions of quantum mechanics. Once Bell's inequality is falsified, it is assumed that quantum information is superluminal propagation.

Bell denoted one variable by λ. The λ represents Einstein's elements of reality that leads to the measurement outcome in question. In the Bohm's electron spin experiments, random variables A, B and C are in Bell's notation function A (a, λ), A (b, λ) and A (c, λ), which can assume the values +1 or −1. For any hidden variable theory of local realism, experimental statistical average data A (a, λ) A (b, λ), A (a, λ)A (c, λ) and A (b, λ)A (c, λ) in three groups (a, b), (a, c), and (b, c) experiments should satisfy the following Bell inequality:

$$A(a,\lambda)A(b,\lambda)+A(a,\lambda)A(c,\lambda)-A(b,\lambda)A(c,\lambda)\leq +1 \quad (1)$$

In 1972, the first experiment to verify the non-locality of quantum mechanics appeared. Most of the subsequent experiments used two-photon spin experiments. In 1982, French physicist Alan Aspect and his follows organized a strict test of Bell's inequality. since 1997, later experiments including the photon entanglement experiments at Innsbruck University in Austria, and the similar experiments by Chinese physicist Pan-Jianwei [6]. These multi-photon entanglement experiments have strongly supported quantum mechanics and the Bell inequality was denied. A saying that quantum information is superluminal propagation, quantum entanglements are superluminal invisible teleportations, is spread everywhere in physicists, philosophers, and the general public. During 2011-2012, Townsend Reuters Group predicted that Aspect, Zeilinger, Clauser, and Bennett's experiments will receive the Nobel Prize in physics. But so far, such predictions have been defeated. According to Eberhard's theorem in 1978, even if there is quantum entanglement associated with at-a-distance effects and global correlations, quantum mechanics prohibits non-local correlation between instrument settings, and quantum information can only be transmitted by clasical channels after measurement.

In fact, Karl Popper had noticed that Bohm used the spin of a particle to restate the EPR experiment that is different from Einstein's thinking, because the spin of a particle is a non-classical quantum effect and spin itself has quantum non-locality. Later, the various tests of Bell's inequality only refuted the Bohm version of EPR argument and could not really refute the original EPR argument [7]. Popper believed that quantum non-locality may be used to engage in absolute simultaneous signal pairs, thus requiring us to abandon Einstein's special theory of relativity, and return to Lorentz's electronic theory that uses the uniformity of cosmic background radiation and isotropy as a new evidence of the existence of absolute space [7].

After the emergence of a large number of disproof experiments in Bell inequality, it was argued that quantum mechanics has non-localized features that have become the mainstream trend of physics research, even in the frontier exploration of quantum gravity. Various hypotheses, theories, and models are forced to accept quantum non-locality that conflicts with the spirit of relativity.

As an attempt to advance the unified field theory in the framework of quantum field theory, the early string theory even introduced the tachyons of faster-than-light motion. After eliminating the tachyons and introducing the curling extra dimensions, string theory can obtain general relativity under low energy approximation, and achieve the renormalization of gravitational quantification in the 2-circle Feynman graphs calculation. The EPR problem appears in the string theory such as in quantum mechanics and quantum field theory.

In the loop quantum gravity theory, the basic unit of quantum information goes deep into the Planck scale, and the entanglement between quantum states with different areas becomes the basis of the emergence of non-locality in quantized space. Some models link the microscopic geometric topology of quantum entanglement with the wormholes in general relativity, and completely non-local quantum space-time.

Wen Xiaogang, who won the Dirac Prize on August 8, 2018, believes that "topological order" represents a new world view. Quantum entanglement and quantum information are the basic elements of the physical world——quantum bits, space is the ocean composed of quantum bits, the basic particles are the fluctuating vortex of quantum bits, and the properties and laws of the basic particles The organizational structure originated from qubits ocean, that is, the topological order of qubits.

2. The Bell's Inequality and the EPR Argument

In 1932, von Neumann gave an argument that quantum mechanics did not have hidden variables, but Bohm revived hidden variables. Hermann discovered that Neumann's argument is a circular argument. Professor Wang-Guowen believes that the Bell's inequality contains similar argument defects, which are based on three different assumptions: (1) Quantum mechanics is effective; (2) Einstein's local realism is correct; (3) Observations are statistical average of hidden variables. Bell's inequality is falsified, its reason may be due to the assumption that the observation is not the statistical average of hidden variables. We can still adhere to Einstein's local realism and negate the superluminal transmission of quantum information.

Karl Hess revealed that the Bell's inequality derivation ignores the timing mechanism of light signals in the special theory of relativity in his work '*Einstein was right*!' Karl Hess pointed out that "*The EPR experiment was dealing with correlations implied always some 'simultaneity', a concept that had played a major role in Einstein's relativity theory.*" [8] As he said, "*The correlated pair had to be measured 'simultaneously', or at least at highly correlated times, at two different locations.*" [8]

"Everyone knows that time is not a random variable, while Bell's λ was thought to be one; thus λ and time or space-time have to be mathematically distinguished" [8]. *"Bell's way worked only for λs representing colored or flavored marbles, or elementary particles, not for their dynamics and their relations to the measurement equipment and to each other. Equipment setting and measurement times cannot be treated as independent mathematical variables!"* [8] Karl Hess believes that time variables should also be used as a real element into the inequality considered by John Bell, this gives a new inequality that is different from the original version of the Bell's inequality. As he said: "*If all the equipment stands still in a laboratory, as it usually does, we may replace space-time just by the number i of the actual experiment. Then, time is just regarded as an order parameter, which provides order as we are counting.* " [8] Thus, Hess's new inequality reads

$$A^{i}_{a}(\lambda_i)A^{i'}_{b}(\lambda_i)+A^{i+1}_{a}(\lambda_{i+1})A_c^{i'+1}(\lambda_{i+1})-A_b^{i+2}(\lambda_{i+2})A_c^{i'+2}(\lambda_{i+2})\leq+3. \quad (2)$$

This new Hess's inequality, contrary to the popular Bell's inequality, does not impose any mathematical restrictions on the measurement results. It is always correct and does not give a deterministic difference between the theory of domain implicit variables and quantum mechanics. Therefore, the experimental test of Bell inequality is not sufficient to rule out local realism. This type of experiment involves two experiments in the space-like region to perform the timing operation of optical signal pairs during their respective measurement periods, thus not meeting the requirements of the EPR argument.

Joy Christian tried to illuminate that quantum entanglement is an illusion in his work '*Disproof of Bell's theorem*'. He found that the completeness standard of Bell's inequality and the completeness standard of EPR argument have different topological space structures. In Bell's inequality, the product of a 3-vector real space and a 'complete' state space is projected onto the 0-sphere of the unit of {-1, +1}, that is projected to two unconnected unit points: *"$A_n(\lambda):R^3\times\Lambda\rightarrow S^0$", where R is a real space of 3-vectors, Λ is a space of 'complete' states, and S_0 is a unit 0-ball"* [9]. In the EPR argument, the product of a 3-vector real space and a 'complete' state space is projected to a 3-Dimensional spherical surface and further projected to a 4-dimensional space-time. So the topologically correct local maps are *"$A_n(\lambda):R^3\times\Lambda\rightarrow S^2$"* [9, p92]. *"Evidently, the range of these maps is still the set of points describing the binary results, ±1, but this set now has the topology of a 2-sphere rather than a 0-sphere."* [9] The value space of quantum states preset by Bell's inequality is inconsistent with the requirements of the completeness of EPR arguments. Along such a line of thought, Joy Christian discussed the real origin of the local realism of quantum correlation. He used the value local variables of Clifford algebra to give a negative proof of Bell's inequality, and analyzed the reasoning of GHZ theorem and Hardy theorem of Bell's inequality. Joy Christian believed that the real elements of EPR is in the unit 2-sphere, not in the 0-sphere envisaged by John Bell. Therefore, after analyzing the various multi-photons entangled topological spaces, he found that their dimensions are not consistent with the dimensions of the popular quantum information space. This exposes that the non-locality of quantum entanglement is an illusion.

3. Quantum Teleportation

Among various EPR correlation phenomena, telepartation seems to be instantaneous communication and convey some magical property of quantum world. Different interpretations of wave function *"allow mystical presentations of quantum information at both popular and scientific level."* [10] As Suresh C. Tiwari said, quantum information science have three main applications, "*namely quantum cryptography, quantum teleportation and quantum computers.*" [10]

"*Quantum cryptography: Wiesner's 1970 paper (unpublished until 1983) is considered the beginning of quantum cryptography (QK)……Quantum mechanics can be used for much more secure communication, Bennett and Brassard proposed uncertainty principle and Ekert proposed entanglement for quantum key distributions.*" [10]

"*Quantum Teleportation: Quantum dense coding was devised in 1992, while quantum teleportation was proposed by Bennett et al in 1993. In their paper authors mention that Einstein himself used the word 'telepathically' in the context of EPR correlations. An interesting point from the historical perspective is that Penrose in 1989 discussed teleportation machine of science fiction and made some comments in relation with quantum mechanics and split-brain experiments.*" [10]

"*Quantum Computer: Reversibility of computation process, both for Turing machines and logic gates proved by Bennett, and construction of Fradkin and Toffoli gates for computation without energy dissipation have been fundamental for quantum computation as quantum mechanics is reversible. Beniokff's work and Feymann followed Deutsch's seminal papers on quantum Turing machine and network model originated the field of quantum computers.*" [10]

Any EPR correlation is a non-local holistic phenomenon. As Nicolas Gisin said: "*The idea of a non-local whole immediately evokes the concept of 'instantaneous communication'*" [11] But in quantum mechanics, *"Determinism means that communication without transmission can be realized."* [11] Various Bell-type experiments show real non-local randomness, *"In principle, there is no reason to prohibit this randomness from happening in different places at the same time, as long as it can not be used to achieve communication."* [11] *"The fact that communication can not be realized avoids the direct conflict between quantum mechanics and relativity."* [11] Using quantum non-local randomness to generate random numbers, we can manufacture quantum random number generators, and establish quantum cryptography: *"If Alice's results is entangled with Bob's one, they can produce a string of results that can be used immediately as encoding keys. And according to the quantum non-clonal theorem, they can ensure that no one else has their key."* [11]

Quantum teleportation can only be done through joint measurements by both experimenters, communication between them that does not exceed the speed of light is indispensable. Moreover, quantum teleportation can hardly be used to transmit a large object, because the quantum entanglements between the particles that make up an object are so fragile that these entanglements are easily destroyed by various disturbances, the entire transmission process is completely impossible.

Non-orthogonality and entanglement make quantum information different from classical information. As Dennis Dieks said, because identical particles reject the concept of local particles, "*In the general quantum situation, 'particle properties' do not combine to form individual particle states*" [12], "*quantum particles can be characterized by fixed algebras of operators plus pure quantum states.*" [12] Proper mixtures and improper mixtures coming from entangled states don't individuate particles. "*Since the violation of Bell inequalities is commonly acknowledged to demonstrate that no local account can be given of what happens in an EPR experiment*" [12], "*The standard story is instead that there are two localized particles, but that a measurement on particle 1 instantaneously changes some feature of particle 2. This story presupposes the traditional concept of a particle with its own individual properties.*" [12] Dennis Dieks's analysis *"goes against this standard story by arguing that the traditional conceptual framework is inadequate."* [12] He constructs an EPR experiment about a physical field without particle concept: *"Classical fields could have the same numerical values for their field strengths at L and R, but these field strengths would obviously not be identical in the metaphysical sense (according to which two identical things are one and the same). The proposal for the quantum case that we are considering is very different: at both L and R we can make contact with the identically same spin state —it is as if both L and R are windows through which we are able to look at exactly the same scene (which itself is not spatial). As it turns out, this picture leads to an explanation of the EPR-Bohm experiment that may be called 'local', even though this explanation is essentially non-classical and dispenses with the particle picture."* [12]

The no-cloning theorem prevents the use of redundancy error correction techniques on quantum states, and it is involved in quantum cryptography and quantum error correction. The first proof was originally given in Dieks (1982) and Wootters and Zurek (1982), their paper showed that cloning violates linearity of quantum mechanics.[13] Yuen (1986) gave another proof, the no-cloning theorem can be used to prove the impossibility of determining the state of a single quantum system: "*No deterministic transformation can produce two identical copies of a state drawn from a set of two non-orthogonal pure states.*" [13] "*The problem of cloning was raised by Herbert (1982), where a protocol for superluminal (actually instantaneous!) communication was proposed, based on local measurements on two entangled systems, and using stimulated laser emission as a cloning device at the receiver.* " [13] As Giacomo Mauro D'Ariano, Giulio Chiribella, Paolo Perinotti said: "*The impossibility of communication without interaction using a shared entangled state is just an immediate consequence of the causality principle.*" [13] The causality principle is corresponding to the request that future choices cannot influence the present, "*No Signaling From the Future*" [13]. They called Operational Probabilistic Theories as OPT, and said: "*Indeed, quantum theory, being a causal OPT, cannot violate Einstein locality. The correlations produced by quantum entangled states are 'non-local', in the sense that they cannot be achieved by local hidden variables, but still they cannot be used for superluminal communications, thus not violating Einstein locality.* " [13]

Giacomo Mauro D'Ariano, Giulio Chiribella, Paolo Perinotti gave a proof on '*No Signaling at a Distance*' as follows [13].

"Theorem 5.6 (No Signaling Without Interaction) In a causal OPT it is impossible to send signals by performing only local tests.

Proof Suppose the general situation in which two 'distance' parties Alice and Bob share a bipartite state $|\Psi)_{AB}$ *of system A and B. Alice performs her local test* $\{A_i\}_{i\in X}$ *on system A and similarly Bob performs his local test* $\{B_j\}_{j\in Y}$ *on system B. The joint probability of their outcomes is*

$$p_{ij} = (e|_{AB}(A_i \otimes B_j)|\psi)_{AB}$$

The marginal probability p_i^A *at Alice and* p_j^B *at Bob are given by*

$$p_i^A := \sum_j p_{ij},\ p_j^B := \sum_i p_{ij}.$$

Alice's marginal does not depend on the choice of test $\{B_j\}$ *of Bob, since*

$$p_i^{(A)} = \sum_j (e|_A (e|_B (A_i \otimes B_j)|\psi)_{AB} = (e|_A (A \otimes [\sum_j (e|_B B_j])|\psi)_{AB} = (e|_A A_i|\rho)_A,\quad |\rho)_A := (e|_B|\psi)_{AB}, \ldots\ldots$$

The same argument holds for Bob's marginal."

According to Juan Roederer, most discussion about EPR correlations *"mumble something about super-luminal speed of information, teleportation of real things, a particle being in different positions at the same time, etc. to satisfy our (classical world) imagination."* [12] As Richard Feynman said, *"the [quantum] 'paradox' is only a conflict between reality and your feeling of what reality 'ought to be'."* [12]

Juan Roederer thought that some conceptual fictions in quantum mechanics have led us into various quantum non-local illusions, and *"the World, both physical and biological, does not operate on the basis of what happens in Mach-Zehnder interferometers, Stern-Gerlash experiments, two-slit diffraction laboratory setups, qubit teleportation designed and information per se. In reality, all such experiments, while providing answers to the inborn human inquiry about how our environment works, are but artificial intrusions poking into a Universe that does not care about linear algebra, Hamiltonians, and information per se."* [12]

Aephraim M. Steinberg found that the superluminal phenomena can never be observed if someone traces the center of mass of an incident wave packet in the quantum tunneling effects. Only when the part of an outgoing wave is projected separately, the propagation of the wave peak appears to exceed the speed of light, which is a non-local phenomenon similar to the collapse of the wave packet [14].

4. Conclusion

It seems that the popular theories that quantum information exceeds the speed of light are rooted in Bell's inequality that violates the requirements of EPR arguments. Once the method of space-time geometry analysis in the relativity is extended to the new field of quantum information research, modern physics will show a wonderful new world of inherent unity, and will not become an illusory mirage because of the division of philosophical interpretations of quantum mechanics.

The mainstream quantum gravity researches have made great progress, but there are many disagreements. According to Einstein's local realism, some new interpretations and new representations of quantum mechanics are given, which may open up new ideas for quantum gravity researches.

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References

[1] Jin Shangnian, The physical foundation and philosophical background of quantum mechanics, Fudan university press, Shanghai, China, 2007, p60-61.

[2] A. Einstein, N. Rosen and B. Podolsky, Can Quantum Mechanics description of physical reality be considered complete? Physics Review, 47, 777 (1935).

[3] N. Bohr, Can Quantum Mechanics description of physical reality be considered complete? Physics Review, 48, 696 (1935).

[4] David Bohm, A suggested interpretation of the quantum theory in term of 'hidden variables', Part I, Physics Review, 85, 166-179, 1952.

[5] J. S. Bell, Speakable and Unspeakable in Quantum Mechanics, Cambridge University Press, Revised edition, 2004, p20.

[6] D. Bouwmeester, J.-W. Pan, K. Mattle, M. Eibl, H. Weinfurter & A. Zeilinger. Experimental Quantum Teleportation. Nature 390, 575, (1997).

[7] Karl Popper, Postscript to the Logic of Scientific Discovery, Chinese Edition, translated by Li-Benzhen, Liu-Guoliang, China Academy of Fine Arts Publishing House, 2014, p194, p222.

[8] Karl Hess, Einstein was right! Pan Stanford Publishing Pte. Ltd, 2015, p47, p48, p52.

[9] Joy Christian. Disproof of Bell's theorem, Brown Walker Press, Second edition, 2014, p84-85, p92.

[10] Suresh C. Tiwari, Superluminal Phenomena in Modern Perspective, Rinton Press, 2003, p158, p159, p161.

[11] Nicolas Gisin, L'impensable Hasard, Non-localité, téléportation et autres merveilles quantiques, the Simplified Chinese edition, Shanghai Scientific & Technical Publisher, 2016, p44, p46, p50, p73, p89.

[12] Edited by Olimpia Lombardi, Sebastion Fortin, Federico Holik and Cristian López, What is Quantum Information? Cambridge University Press, 2017, p97-110, p136.

[13] Giacomo Mauro D'Ariano, Giulio Chiribella, Paolo Perinotti, Quantum Theory from First Principles: An Informational Approach, Cambridge University Press, 2017. p60-77, p142-156.

[14] Edited by John D. Barrow, Paul C. W. Davies, Charles L. Harper, Science and Ultimate Reality: Quantum Theory, Cosmology and Complexity, Simplified Chinese edition translated by Zhu-Yunhui, Luo Xuan, Lei –Yi-An according to Cambridge University Press 2004, p142.