American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-14, Issue-1, pp-33-46
www.ajer.org
Research Paper Open Access

Bell's inequality and local realism

Wu Xinzhong
School of Science History and Science Culture
Shanghai Jiao Tong University

[Abstract] *This article examines the history from EPR argumentation to Bell's inequality, as well as the impact of Bell's inequality on the exploration of the frontier of quantum mechanics. It is found that Bell's inequality has some hidden assumptions different from EPR arguments. Following Schrödinger's assumption that the measurement process of EPR experiments requires time, Karl Hess treated time as a temporal hidden variable, and Joy Christian obtained a local hidden variable inequality different from Bell's inequality. They extended the space-time geometry analysis method of relativity to the local geometric morphology analysis of quantum states, and believed that the reasoning of Bell's inequality did not meet the completeness requirement of EPR argumentation. In order to adhere to local realism, we need to replace realism at the eigenvalue level with realism at the phase factor level, and explain the quantum non-local phenomenon as the global correlation set by the measuring instrument according to the laws of nature.*

[Keywords] Quantum Information, Bell's inequality, local realism

---

Date of Submission: 09-01-2025 Date of acceptance: 22-01-2025

The experimental verification of Bell's inequality has won the Nobel Prize in Physics in 2022, but physicists have found that the premise of Bell's inequality does not meet the quantum mechanical completeness standard of EPR proof, nor does it support the ability of quantum information to propagate faster than light. However, defending Einstein's local realism from the perspective of phase factor realism has not yet received a response from mainstream physicists.

I. Why Bell's inequality is wrong?

In the history of the development of quantum mechanics, there has always been a competition between the Copenhagen School of matrix mechanics represented by Niels Bohr, Heisenberg, and Max Born, and the wave mechanics school represented by Einstein, de Broglie, and Schrödinger. The subsequent development of quantum mechanics mainly adopts the Schrödinger equation of the wave mechanics school in mathematical physics, while it mainly follows the Copenhagen School's philosophical interpretation to understand quantum probability, uncertainty relations, and complementarity principles. An important competition between Einstein and the Copenhagen School was the proposal of the EPR argument in 1935. Einstein, Podolsky and Rosen attempted to prove that the measurement of one particle should not affect the state of the other particle in the absence of interaction between two separated particles. On the other hand, quantum mechanics provided that when we independently measure these two particles, the determination of the quantum state of one particle seemed to instantly determine the state of the other particle. Quantum mechanics did not provide a hidden mechanism for this influence, and therefore it is incomplete.

Bohr believed that Einstein and others' EPR argument ignored the failure of the law of conservation of momentum in quantum measurement processes, avoiding the possibility of instantaneous effects in the quantum states of two particles as envisioned by Einstein. In the original debate between Bohr and Einstein, the issue of quantum information traveling faster than light did not arise. In the 1950s, with the development of David Bohm's theory of hidden variables in quantum potential, people began to raise questions about the existence of local hidden variables in the quantum state correlations mentioned by Einstein in the EPR argument and the quantum entanglement mentioned by Schrödinger. However, Bohm's non local quantum potential theory, although capable of explaining a large number of quantum mechanical problems, posed a huge challenge to the

Copenhagen interpretation, but Einstein was not satisfied with this cheap explanation that violated the spirit of relativity. Bohm only acknowledged influences at a distance between quantum states, and expressed the quantum wholeness advocated by the Copenhagen School in different ways, but did not believe that information can be transmitted faster than light.

In 1964, John Bell proposed a set of inequalities about the theory of local latent variables in '*On the EPR Paradox',* arguing that the predictions of quantum mechanics must violate this inequality: *"In a theory inwhich parameters are added to quantum mechanics to determine the result of individual measurements without changing its statistical predictions, there must be some mechanism whereby the setting of one measuring device can influence the reading of another instrument, however remote. Moreover, the signals involved must propagate instantaneously, so that such a theory could not be Lorentz invariant*." [1] Therefore, no local hidden variable theory can fully reproduce all experimental predictions of quantum mechanics. Once Bell's inequality is proven false, We need to assume a certain kind of superluminal teleportation of quantum states.

John Bell defined a hidden variable λ that represents Einstein's reality elements that lead to the measurement outcome in question. In the Bohm's electron spin experiments, the random variables A, B and C of Bohm electron spin experiment are Bell's label functions A (a, λ), A (b, λ) and A (c, λ), which can be assumed to be + 1 or - 1.For any local hidden variable theory, Bell's inequality should be satisfied among three sets of experimental statistical mean dataA(a,λ)A(b,λ)， A(a,λ)A(c,λ) and A(b,λ)A(c,λ):

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

The first experiment to verify the non locality of quantum mechanics appeared in 1972, and most subsequent experiments used two-photon spin experiments. In 1982, Alain Aspect from France organized a rigorous test of Bell's inequality. Subsequent experiments, including photon entanglement experiments at the University of Innsbruck in Austria since 1997, as well as multi photon entanglement experiments conducted by Chinese physicist Pan Jianwei and others, strongly supported quantum mechanics and falsified Bell's inequality. The notion that quantum information travel faster than light and quantum entanglements teleport faster than light are widely circulated in the physics community, philosophers, and the general public. In 2011-2012, Thomson Reuters predicted Alain ASpect, Anton Zeilinger，John Clasuser， Bennett and others' experiments will win the Nobel Prize in Physics. In 2022, French scientist Alain Aspect, American scientist John Clauser, and Austrian scientist Anton Zeilinger were awarded the Nobel Prize in Physics for their contributions to entangled photon experiments, proving violations of Bell's inequality, and pioneering quantum information science. Regarding the question of whether we can use this quantum non locality to transmit useful signals, Alan Aspect believes that 'although quantum mechanics can perform extremely accurate calculations of the probabilities of various possible outcomes in experiments, these probabilities only have statistical significance when the same experiment is repeated multiple times. It is this fundamental quantum randomness that prohibits the superluminal propagation of information'[2,p3].In the view of Nicolas Gisin, Einstein's so-called 'ghost-like interactions' are the remote coordination made by nature according to quantum rules, but not quantum communication [2, p44]. He believes that there are still detection loopholes and locality loopholes in the experimental verification of Bell's inequality [2, p110-11]. According to Eberhard's theorem in 1978, even if there seems to be quantum entanglement with remote effects and global correlations, quantum mechanics does not allow non local correlations between instrument settings, and quantum information can only be transmitted through classical channels after measurement. Meanwhile, the correlation of quantum entangled states involves a set of quantum superposition states separated by class space, seemingly influenced by quantum states measured from a distance. However, which eigenstates appear in the quantum superposition state still have randomness. Therefore, the so-called superluminal phenomena of quantum entanglement teleportation involves quantum random states and are by no means the real quantum information transmissions.

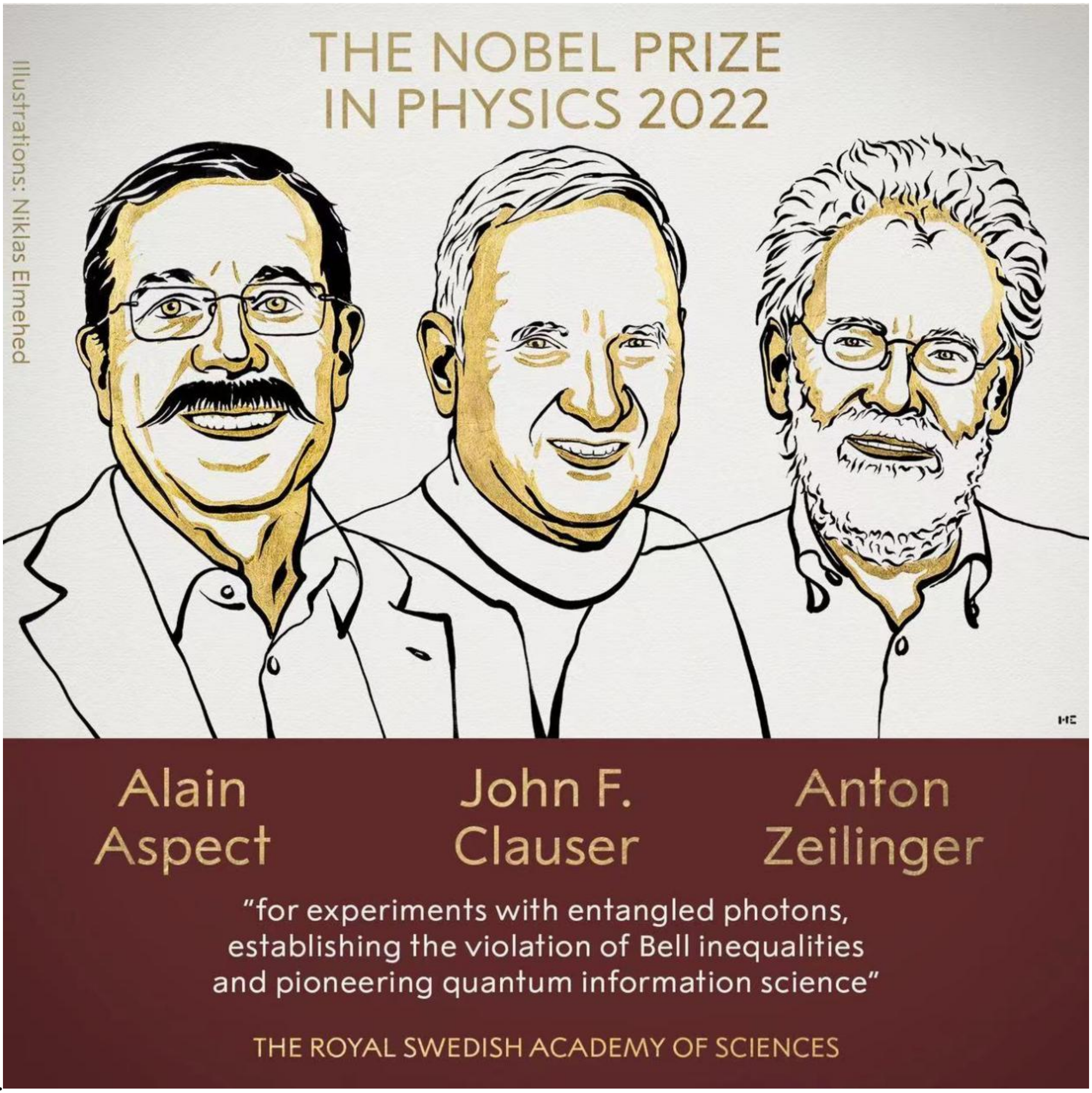

Fig 1. The Nobel Prize in physics 2022

In fact, Karl Popper had early noticed that Bohm's use of particle spin to rephrase the EPR experiment differed from Einstein's approach, as spin is a non classical quantum effect and itself may have quantum non locality. Later on, various tests of Bell's inequality only refuted the Bohm version of the argument, and could not truly refute the original EPR argument. Karl Popper believed that quantum non locality could be used to achieve absolute simultaneity in signal timing, thus requiring us to abandon Einstein's special relativity, return to Lorentz's electron theory, and use the uniformity and isotropy of cosmic background radiation as new evidence for the existence of absolute space.

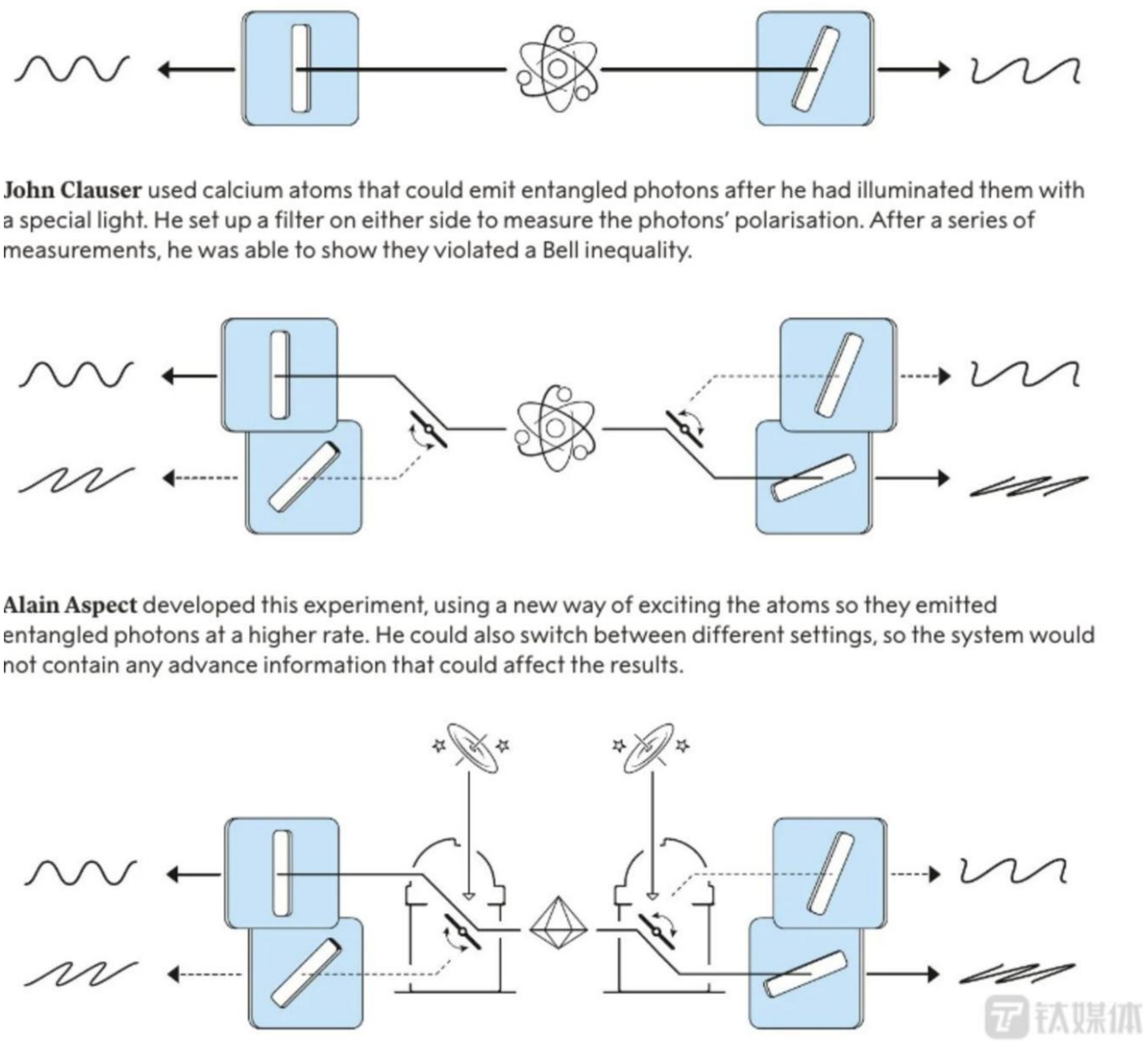

Fig 2. Bell's type expriments

As early as 1932, von Neumann provided the proof that there are no hidden variables in quantum mechanics, but Bohm revived the hidden variables, and Hermann discovered that Neumann's proof was a circular proof. Professor Wang Guowen believes that Bell's inequality contains similar argumentative flaws and is based on three different assumptions: (1) quantum mechanics is effective; (2) Einstein's local realism holds true; (3) Observation is the statistical mean of hidden variables. The Bell inequality has been proven to be false, and the problem may lie in the assumption that the observed quantity is not the statistical average of the hidden variable. We can still adhere to Einstein's local realism and deny the superluminal transmission of quantum information.

Karl Hess revealed in his book 'Einstein is Right' that the derivation of Bell's inequality ignored the mechanism of light signal timing in special relativity. Karl Hess believed that EPR experiments involve correlations, and correlations always imply some important 'simultaneity' concepts in relativity: correlation pairs must be measured simultaneously at two different positions, or at least at highly correlated times.

Everyone knows that the measured time is not a random variable and follows an order, but Bell's hidden variable λ is assumed to be a random variable and it is independent of the experimental setup; Therefore, λ and time or spacetime must be mathematically identifiable. Bell's method is only applicable to the representation of colors, flavors, marbles, or elementary particles by λ, rather than their dynamics or their relationship with measuring instruments. The experimental setup and measurement time cannot be treated as independent mathematical variables. The repeated use of the λ hidden variable in a given inequality, as well as the assumption that various hidden variables and experimental devices are independent variables, have become the cornerstone of Bell's inequality. But Hess believed that this cornerstone was suspicious. If time is used as the order parameter of quantum mechanics to provide the time sequence of measurement results, then a different inequality from Bell can be obtained: it can guarantee correctness without imposing limitations on experimental results. Therefore, the experimental verification of Bell's inequality is invalid for excluding local realism. The verification of Bell's inequality involves comparing the optical signals of two experiments in a class empty region during their respective time periods, and it does not meet the requirements of EPR proof.

Karl Hess developed Schrodinger's assumption that the measurement process of EPR experiment would take time. He believed 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.*"[3].Therefore, correlation pairs in EPR experiments must be measured at two different locations at the same time, or at least at a time of high correlation. Everyone knows that time is not a random variable and has a past-present-future time series, while Bell's λ is assumed to be a random variable; therefore, λ and time or space-time must be mathematically identifiable. Time variables should also be taken as real elements and entered into Bell's inequalities, but Bell's inequalities does not take time variables into account.

Karl Hess believed *"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.* " [3,p52]Thus, Karl Hess got an inequality different from Bell's inequality:

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

This inequality, contrary to the popular Bell's inequality, does not impose any mathematical restrictions on the measurement results. It is always right and does not give a decisive difference between local implicit variable theory and quantum mechanics. Therefore, the experimental test of Bell's inequality is not enough to exclude the local realism; this kind of experiment involves two experiments in the space-like region to make the operation agreement of optical signal timing in their respective measurement time periods, thus not meeting the requirements of EPR argument.[4] In 1988, Chinese historian and philosopher of science Jin Guantao believed that quantum phenomena are not elementary physical phenomena, but rather an emergent phenomena constructed through the detection of microscopic particles by instruments, the reaction of instruments on microscopic particles is a boundary response that creates quantum eigenstates. Jin Guantao pointed out that although the tests of Bell's inequality falsify the theory of local hidden variables, it is the quantum non local correlation implied in the EPR experiment, which is only an experimental instrument correlation to maintain the spin conservation of Bohm electron pairs. The natural laws of conservation of energy, momentum, and angular momentum are essentially isomorphic to the principles of various controlled experimental instruments.[5,p102-103] According to Jin Guantao's constructivism, the local hidden variables λ of Bell's inequality are not intrinsic variables of microscopic objects, but unknown properties of experimental devices. The arrangement of instruments in the experiment must conform to a certain natural law, which leads to the global correlation of quantum measurement results.

In his article '*Bell's Inequality and Distance Effect*', Karl Hess pointed out that there are a lot of literatures published by scholars involved in the controversy of Bell's Inequality. The famous scholars are L. Accardy, J. Christian, H. A. De Raedt, A. Khrennikov, M. Kupczinsky, K. Michielson, T. Nieuwenhuisen, W. Philipp, L. Sica, Karl Hess and others [4,p1574-1575]. Karl Hess, in other papers, argued that EPR experiments are interpreted according to Bell model without considering all the hidden variables and introducing some inferences of counterfactual conditions. There are always loopholes in the experimental verification of Bell inequality, so it will not disprove the local realism [6,p713-733].

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 (λ):$R^3\times\Lambda\rightarrow S^0$, where R is a real space of 3-vectors, Λ is a space of 'complete' states, and S_0 is a unit 0-ball"* [7,p84-85]. 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 (λ):$R^3\times\Lambda\rightarrow S^2$ "*[7,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."*[7,p92]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 as Joy

Christian said:

"*Classical reality has far deeper topological structure than what Bell theories seem to recognize……just as Newtonians——with their Kantian commitments to 'non-locality'——believed that spacetime is always flat and rigid regardless of what matter fields are present,Bell theorists believe that EPR elements of reality are always lined up as points of the real line,regardless of which system is being considered.But it is abundantly clear from EPR that the elements of reality they argued for are ordered as points of 2-sphere(in the case of the singlet state),not lined up as the real line. More generally,in the cases considered by Hardy and GHZ,the elements of reality are ordered as points of a 3 or 7-sphere.*"[7,p135] "*Assuming now that the distribution ρ(λ) is normalized on the space Λ,we finally arrive at the inequalities*

$-2\sqrt{2} \le \varepsilon(a,b)+\varepsilon(a,b')+\varepsilon(a',b)-\varepsilon(a',b') \le +2\sqrt{2}$.

This is of course exactly what is predicted by quantum mechanics…….All we need to assume, in fact,is that the distribution ρ(λ) remains normalized on the space Λ of complete.This implies that the violations of Bell inequalities are purely topological phenomena that have nothing to do with quantum mechanics per se."[7,p103]

It seems that the popular notion that quantum information travels faster than light is rooted in Bell's inequality, which violates the requirements of EPR proof. Once the analysis methods of spacetime geometry in relativity are extended to the new field of quantum information research, modern physics will exhibit an internally unified and extraordinary phenomenon, rather than becoming an illusory mirage due to the splitting of philosophical interpretations of quantum mechanics.

II. Quantum theory and local realism

In relativistic quantum field theory, Lorentz covariance and locality are statistical effects, and the quantum effects of a single process can lead to the breaking of Lorentz covariance, while the quantization of the field exhibits non locality effects. In quantum field theory, EPR correlations are also commonly present. For example, Rindler quantized the EPR correlations of vacuum fluctuations in space-like regions of Minkowski spacetime [8, p293-301]. Dirac discovered in the 1950s the possibility of restoring the mechanical ether concept and absolute spacetime view abandoned by special relativity in quantum field theory. In 1951, he noted that if the wave function assigns equal probabilities to all ether velocities, quantum mechanics can link the physical equivalence of all Lorentz reference frames to the selection of preferred spacetime directions at each point through mechanical ether. Dirac formulated this thesis in 1953, pointing out that in quantum texts, the concepts of absolute simultaneity and absolute time are also compatible with Lorentz covariance. Although we have not yet discovered the type of mechanical ether envisioned by Dirac, it is clear that absolute time plays an important role in causal theory [9, p529-530]. Thomas Durt believes that physicists can design quantum simulation experiments of Michelson Morly's experiment to reveal the existence of 'quantumether wind' in the process of wave packet collapse [9,p9-14]. Therefore, the mathematical equivalence between Lorentz electron theory and Einstein's special relativity is only valid at the classical level, while at the quantum level, Lorentz electron theory shows a conflict with special relativity, not just a difference in philosophical interpretation of spacetime. However, the difference between Lorentz electron theory and Einstein's theory of relativity at the quantum level can be understood as the difference between a reference frame that remains stationary in a uniformly isotropic microwave background radiation and a reference frame that moves uniformly in the microwave background radiation,while these two reference frames involve different distant spatial boundary conditions. We believe that Lorentz electron theory and Einstein's special relativity do not exhibit differences in distant boundary conditions at the classical level, as the boundary conditions conform to the Lorentz transformation. However, at the quantum level, due to the response of quantum wave functions to the boundary conditions, Lorentz electron theory seems to be more likely to demonstrate the 'quantum etherwind' effect of this boundary response [10, p9-14].

Indian physicist S. Unnikrishnan of the De Broglie school drew inspiration from de Broglie's concept of phase waves and advocated that the essence of complex waves displayed by quantum systems is the core of non classical features of quantum phenomena, which is close to Penrose's position. However, he further pointed out that the widely discussed mystery of EPR non-locality is still unsolvable, as the phase correlation between the localized quantities of an associated quantum system has not been considered. He believes that if quantum correlations are recalculated under strict assumptions of locality, then we prove that the EPR mystery can be solved. However, this requires replacing realism at the eigenvalue level with realism at the phase factor level. This implies that measuring a particle does not cause the relevant particles to collapse into a certain state. In addition to solving the EPR mystery, this study demonstrates that the physical explanation for surface 'non local' effects similar to quantum communication and entanglement swapping is different from what is commonly assumed. Bell type measurement does not cause wave packet collapse. However, once measured, the correlation can be accurately reproduced due to the quantum correlation at the source.

Unnikrishnan believes that the calculation of quantum correlations should use probability amplitudes instead of averaging the results of eigenvalues. These probability amplitudes are purely localized quantities that describe the behavior of individual particles locally and separately. However, when entangled multi particle wavelet functions are used, the possibility of strict local description is unrealistic. The square of the probability amplitude gives the probability of local measurement. The correlation between several particles separated in the class space region at the source is encoded in the mutual correlation or relationship phase of these probability amplitudes. It is very clear that these correlations are obtained by first considering a suitable product of probability amplitudes and then squaring these probability amplitude correlations, which replaces the simple method of calculating the eigenvalue product and average in local realism theory.

The objective definition of EPR is strongly influenced by classical particle mechanics. This is reflected in the correlation functions in local realism and Bell analysis; The correlation function is the average of the product of the measurement results of two particles. However, this is a serious drawback caused by not retaining important phase information. We will see that if the probability amplitude of each particle is used for calculation, quantum correlations can be reproduced under the assumption of strict locality. This means that the objective definition of EPR is too strict. There exists an objective reality, but not at the level of eigenvalues, but at the level of quantum phase.

Unnikrishnan constructed a new formal system for the Bohm version of the EPR problem, using the same assumptions as Bell, but the correlation function was calculated from the local probability amplitude rather than just the product and average of eigenvalues. This is the main difference between his formal system and Bell's analysis. In the derivation of the standard quantum mechanics approach, we use localized probability amplitudes instead of intrinsic diffusion and non localized multi particle wavelet functions. However, the habitual use of multi particle wavelet functions has replaced the use of localized probability amplitudes or single particle wavelet functions, which has brought false non locality to the description of standard quantum theory.

The new theory also involves the difference between pure and mixed states. There is a subtle but real difference between unmeasured quantum particles that have never entered classical instruments and another state that has already been prepared in a deterministic rather than random, but unknown to the experimenter. In the latter case, there actually exists an unknown eigenvalue that belongs to a mixed state; In the former case, there is no real state that can be attributed to the occurrence at the eigenvalue level, and the state of each particle in an entangled multi particle system is such a pure state, which can be described by the complex probability amplitude. A real measurement involves the interaction of this quantum state with a classical instrument, and the measurement results can be used to predict the results of similar measurements applied to accompanying particles, but according to the new analysis method, there is no non local influence. If we measure, it represents that the measurement result of the second particle can be accurately predicted, and its state is still a pure state rather than a certain eigenvalue as imagined by EPR. Of course, after actual measurement of the second particle, it will enter this eigenvalue. Bohr's distinction between predicting the state of the second particle based on the measurement results of the first particle and actual measurement of the second particle is reasonable, but the analysis remains at the level of phenomenological holism and does not delve into the difference between quantum pure states and mixed states involving phase changes. This means that quantum systems have a deeper level of objective reality than described by the real EPR definition. So, deterministic prediction is not equivalent to a state contraction or measurement, and measuring a particle in EPR pairs does not lead to the widely popular and mistakenly believed non local state contraction. Extending these conclusions to problems such as quantum entanglement swapping in many particles systems, it will be found that the widely circulated non local interpretation of quantum communication is incorrect, as quantum information is locally encoded in internal variables similar to phase factors. Unnikrishnan's new theory changed the classical particle mechanics implications implied by the EPR reality standard, requiring consideration of the objective reality of quantum wave characteristics, and also changed the formulation of quantum measurement problems, that is, quantum measurement theory can be discussed from the perspective of local probability amplitudes and phase factors [11].

C.S. Unnikrishnan cleverly replaced Bohm's non-local quantumpotential with a local phase factor to defend local realism, but in the eyes of most scholars, phase factors, like quantum potentials, are unobservable quantities in quantum mechanics. Using them as theoretical entities in quantum mechanics to defend realism lacks empirical support for directly observable quantities. In 2024, Robert Colub and Steven K.Lamoreaux draw a similar conclusion: "*Testing the Bohm theory requires constructing a physical impossible initial state*."[12]

III. Is quantum physics self consistent?

Niels Bohr sought general relativity to understand Einstein's photon box experiment in 1930, leading people to widely believe that quantum mechanics is logically consistent and potentially compatible with relativity[1,p183-188]. The experimental verification of Bell's inequality has led many physicists to believe that quantum physics can break Lorentz covariance, ultimately breaking through the conceptual framework of relativity and triggering a new revolution in physics.

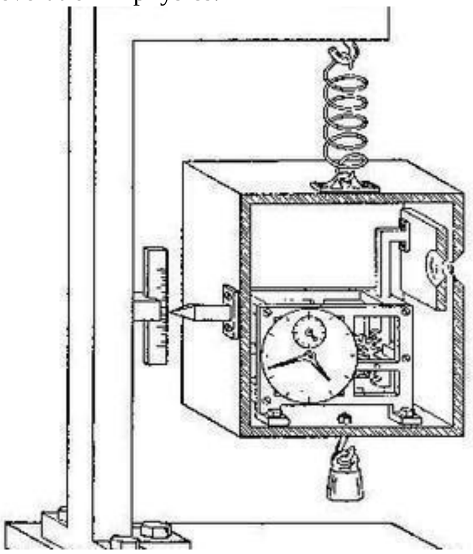

Fig 3. Einstein’s photon box

Kip S. Thorne, who won the Nobel Prize in Physics for discovering gravitational waves in 2017, talked about John Wheeler’s hope for future unification of physics, and pointed out: “*For general relativity and quantum mechanics, in order to logically integrate the two, it is obvious that one or both of them should be modified. If this fusion is achieved, the ultimate unification of general relativity and quantum mechanics will produce a new set of powerful laws, which physicists call it as quantum gravity.”* [13]Physicists have different opinions on the possibility quantum gravity theory, which path to establish quantum gravity theory, and whether the quantum gravity theory can be reconstructed. Therefore, the study of quantum gravity has become an important link to realize the ultimate theoretical dream, and is the ‘Holy Grail’ that theoretical physicists yearn for.

Encouraged by a large number of experiments to prove Bell’s inequality, quantum non-locality, quantum entanglement and quantum information concepts in conflict with relativistic spirit, infiltrate into the theoretical exploration of loop quantum gravity (LQG). While the exploration of loop quantum gravity has been involved in the non-local storm caused by Bell’s inequality, some more radical new physical models have begun to attack the principle of light speed invariance in relativity. More than 20 years ago, Lee Smolin noticed that some special calculations of loop quantum gravity actually contradicted Einstein’s special relativity, which led him to abandon loop quantum gravity and reconsider the string theory with many defects. From Lee Smolin’s sharp criticism of string theory, his pessimistic prediction of the development prospects of loop quantum gravity, and Roger Penrose's controversial exploration of the non-local effect of gravity involved in quantum measurement, we can see that the mainstream exploration of quantum gravity has been seriously misled by Bell’s inequality and has entered a wilderness with many divergences.

But why does quantum field theory need renormalization? Why does quantum gravity face the dilemma of non-renormalizability? A profound reflection on these issues leads us to a higher level of return to the theoretical motivation behind Bohr's unforgettable Einstein photon box experiment: quantum mechanics is inconsistent and conflicts with the spirit of relativity.Chinese physicist Zhang Yongde deeply analyzed the problem of logical self consistency in quantum physics in his book ‘Quantum wisdom root’, attempting to completely negate Einstein’s local realism.

Quantum physics can be divided into three levels: non relativistic quantum mechanics(NRQM), relativistic quantum mechanics(RQM), and quantum field theory(QFT).The difference between NRQM and RQM only involves the difference in energy and the difference in the equation of motion, but their commonality is to maintain the conservation of particle number. QFT, on the other hand, is different from the two. It is a multi particle theory that considers the true generation, annihilation, and transformation of particles, thus breaking through the scope of mechanical theory. However, the commonality among the three is that they all adopt a localized description method that is accurate to the space-time point.

Zhang Yongde believes that the internal logical structure of NRQM is quite self consistent, but a thorough localized description is not suitable for the entire quantum physics[11,p207-208]: “*The Klein paradox fully demonstrates that QT is essentially a multi-body theory with non conserved particle numbers, and ignoring the existence of antiparticle solutions simultaneously is sometimes impossible*”, “*Klein's paradox also directly indicates the applicability of RQM: (1) Compared to the static energy of particles, potential energy is very weak;*

(2) Compared to the Compton wavelengthλ_c, the spatial variation of potential energy is very gentle."[14,p220] In 1985, S. Weinberg pointed out at a conference commemorating the one-year anniversary of Dirac's loss at the University of Cambridge in the United Kingdom: "*One of the symmetries we require seems to be incompatible with quantum mechanics. This symmetry is called Lorentz invariance*", "*Unless it is within the scope of QFT, we cannot combine quantum mechanics with relativity*."[14,p222]

The development from RQM to QFT has solved some of the contradictions of RQM: by breaking the theoretical framework of mechanics and solving the constraint of particle number conservation, the first contradiction of RQM which isthe inherent contradiction between high energy and single particle mechanics theoryhas been eliminated.. However, the current QFT still cannot solve its second contradiction, which is the contradiction between the local description method and the multi particle theory that allows for particle to particle transformation. Zhang Yongde believes that the negation of the local description method by the fluctuation nature of microscopic particles is the root cause of various types of divergence that often occur in QFT calculations, quantum theory is essentially a multi particle, spatially non local, and probabilistic theory.[14,p223-224] However, current experimental exploration of all quantum phenomena relies on particle collisions with measuring instruments, and quantum specificity and wave particle duality are likely the emergence of particles impact instrument process[5,p102-103]. Why should we believe that the quantum rules obtained in this way are still valid in the Compton wavelength scale of spacetime? The process of particle impact on instruments is a relaxation process that tends towards a thermal equilibrium state. The motion states and space-time images of microscopic particles undergo irreversible changes. Extrapolating quantum rules to the inner space-time regions of Compton wavelength scale is as absurd as discussing the embryonic development of eggs using the biochemistry of frozen or roasted eggs.

The relativistic quantum field theory follows the relativistic local causality law. This is reflected in the requirement that experimental measurements taken at two points apart in the quantum field will not affect each other. But in Feynman path integration, the measure of classical paths (and their neighboring paths) that follow the local causality law of relativity is almost zero, and the second type of path that characterizes quantum fluctuations is dense. That is to say, Feynman's postulate contains a large number of second-order paths. They have a profound contradiction with the local causality law of relativity.[14,p282] Except for a classical pathway (and a relatively smooth path regardless of proximity), almost all quantum fluctuation paths violate the local causality law of relativity. But the overall result after superposition follows this law - the ensemble average result is normal.[14,p283]In the spatial separation region outside the light cone, the propagator has asymptotic representation, it decays exponentially to zero, its spatial scale of attenuation is the Compton wavelength $\lambda_c = \frac{\hbar}{mc}$ of a particle. It can be considered that this is due to the inevitable occurrence of QT tunneling effect based on quantum fluctuations in order to localize particles within the Compton wavelength range.[14,p283]

According to Zhang Yongde's analysis of the space-like paths in the Feynman diagram, we found that these space-like paths are equivalent to extrapolating the rules of relativistic quantum field theory to the internal region surrounded by Compton wavelength, where the probability amplitude of quantum processes that disrupt local effects rapidly decays in the normal causal spacetime region outside of Compton wavelength. We can further speculate that string theory describes a large number of physical processes in spacetime regions smaller than the Compton wavelength of particles. These virtual processes are similar to the phantom vibrations formed by quantum wave packets on highly distorted interfaces after the interfaces surrounded by the Compton wavelength of particles undergo strong distortions in interactions, they appear to be strings located in extra dimensional Calabi-Yau space. The early emergence of string theory's tachyon seems to be based on the rules of quantum field theory, which theoretically describe physical processes that violate the causality of relativity within the Compton wavelength.

IV. Quantum mechanics and system science

Quantum mechanics is deeply influenced by the philosophy of atomic theory and reductionism methods. Most scholars view quantum mechanics as a description of microscopic elementary processes, and the Schrödinger equation or Heisenberg matrix are fundamental physical laws similar to Newton's laws of motion. Richard Feynman claimed that quantum electrodynamics solved all the problems in chemistry and the vast majority of physics, and in principle solved the physical and chemical mechanisms of life sciences [15,p6-7]. Wen Xiaogang proposed a very thorough research program on reductionism, which believes that all things originate from quantum ether bits and from ubiquitous quantum entanglement. However, quantum theory originated from the study of blackbody radiation, atomic spectra, and atomic structure, involving the interaction of a large number of electrons, photons, and other fundamental particles. It inevitably involves topics such as statistical ensembles, structural stability of atoms and molecules, and the propagation and regulation of microscopic information in systems science research.

In 1976, Jin Guantao deemed that the process of obtaining micro world information relies on controlled experiments, which means obtaining information through the action of macro objects (or instruments) on them (specific control effects). Therefore, the interaction between macroscopic objects and microscopic states must be included in the theoretical composition.[16,p473]

In Jin Guantao's view, the microscopic object is like a black box. The input of the black box represents the effect of the macroscopic object on the microscopic object, and the output of this black box represents the effect of the microscopic objects on the macroscopic world. Due to this effect, we can see changes in macroscopic phenomena, such as changes in energy and momentum as manifested. This effect can be observed experimentally through certain changes in macroscopic objects. That is to say, in understanding the microcosm, we understand its internal structure through the iterative process of input-output, i.e. control- observation. [16,p474] Mario Bunge expressed a similar viewpoint on quantum measurement in 2006: "*The measured object, the measuring apparatus,and the recording device(whether observer or automated) are interconnected but distinguishable.*"[17,p70] "*And, since measuring instruments are set up and handled by experimenters, one can speak of the object-apparatus-observer supersystem. However, contrary to Copenhagen dogma, this is not an indivisible whole: connection does not entail indistinguishability .*" [17,p70]

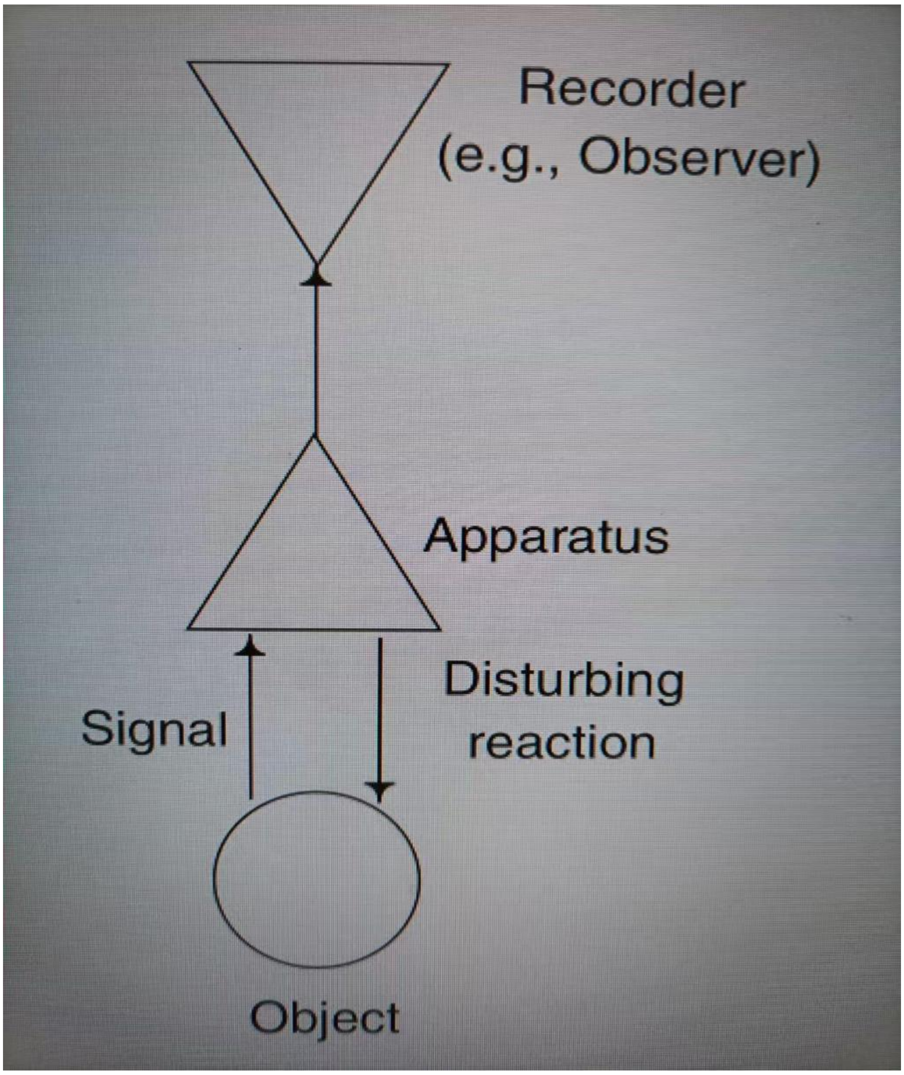

Fig.4 Mario Bunge on quantum measurement [17,p70]

Jin Guantao and Mario Bunge provided cybernetics and systems theory explanations for quantum measurements, which are different from reductionism and holism explanations. Mario Bunge emphasized the objectivity of quantum measurement: "*One can adjust to an instrument without poking into the experimenter's brain.*"[17,p70] This eliminates von Neumann's infinite instrument chain dilemma and the multi-minds explanation of quantum mechanics. In his view, the weakness of von Neumann's measurement theory lies in the arbitrary boundary division of the interaction between subject and object in the quantum measurement process, as well as the arbitrary division between classical and quantum domains, and the Copenhagen interpretation's trouble lies in the mysterious trinity of quantum states referring to objects: the Father (instrument), the Son (microsystem), and the Holy Spirit (observer) are unified into a divine world of quantum phenomena.[18] Peter Atkins, who advocates the theory of decoherence, is also very dissatisfied with the Copenhagen interpretation, the many worlds interpretation, and the von Neumann's measurement theory. [19,p232] He believes that the essential characteristic of a measuring instrument is not that it renders the Schrö dinger equation untenable, as required by the Copenhagen interpretation, but rather that it is a macroscopic quantum mechanical device embedded in its environment.[19,p235]

Unlike most scholars who argue that Bell's inequality excludes local hidden variables and continues to adhere to Einstein's realist position, Jin Guantao believes that by analyzing the cybernetics structure of quantum measurements, we can adhere to Einstein's local position of action throughthe medium and introduce constructivism to correct our concept of objective reality. According to the experiments of operationism psychologists[20], Jin Guantao believes that *'the name of behavior=the name of object'*[5,p41]. According to his cybernetics analysis of cognitive structures based on quantum measurements, Jin Guantao believes that Hermitian operators in quantum mechanics represent experimental operations that control the position, momentum- energy, and other properties of microscopic objects: the non commutativity of quantum mechanics operators represents the mutual exclusion and complementarity of macroscopic experimental operations.[16,p478] Jin Guantao concluded that "*the relationship between a natural law and an instrument is isomorphic. The so-called experimental instruments are just a materialization device that expresses the connection between natural phenomena*."[16,p488] and "*the eigenstates in quantum mechanics and the internal steady states in cybernetics are consistent.*"[5,p47]

According to Von Foerster's constructivist neuropsychology[21], the nervous system never receives external inputs that it is not prepared to accept or has not calculated, which means that nearly all inputs are its own outputs. We can consider the chemical substances filling synaptic gaps as factors that affect the overall structure and function of the nervous system, and these factors are controlled by the output of the nervous system, forming a high-level feedback loop, which is the closure of cognitive structures.[5,p30] Jin Guantao points out that "i*t is the closed nature of neural networks that enables constructivism to derive philosophical conclusions that objective reality cannot be constructed without the observer.*"[5,p31] and "*if we consider the objective reality as the sum of all definite determinacy, then every definite qualitative determinacy is an eigenstate*."[5,p37]

Jin Guantao revisits the objectivity of quantum measurement based on constructivism: "*Generally speaking, in quantum mechanics, since the operator represents the effect of the instrument on the microscopic particles, it represents the macroscopic environment in which the microscopic particles are located. As long as the macroscopic environment (or certain conditions) represented by the operator is not the result of human selection and control, their corresponding microscopic statesψ represent the natural state.……Although philosophers of quantum mechanics can repeatedly emphasize that certain properties of electrons do not exist when the observer does not exist, this does not prevent the entire content of quantum mechanics from actually discussing some objective state that is unrelated to the observer.*"[5,p98]

Jin Guantao believes that the experimental verification of Bell's inequality does not involve the so-called superluminal transmission of signals. Due to the isomorphism of the relationship between natural laws and instruments, when an observer can foresee the observation of another observer based on a certain natural law, it actually means that the other observer can only measure the corresponding observable quantity by adjusting the instrument in a specific way. The correlation between the two observers' choices of instrument states is determined by the construction of the instrument, that is, when designing these instruments and experiments, they are already interrelated.[5,p102]

Jin Guantao provides the following spin correlation experiment to illustrate his viewpoints:"*For example, when observer C maintains the conservation of angular momentum between two particles and directs one particle towards observer A and the other towards observer B. Let A measure a certain quantity of this particle using a certain method. Once A measures a certain value, according to the law of conservation of angular momentum, A's choice will affect the results observed by B when measuring another particle. The reason why experimenters find it difficult to understand this mysterious interconnection is that they view the conservation of angular momentum as a natural law. In fact, according to the isomorphism law between natural laws and instrument principles,in order to maintain the conservation of angular momentum between two particles, C must use a control instrument, which means that these two particles are always the eigenstates controlled by the instrument chosen by C. How can A and B confirm that they are observing a particle pair with angular momentum conservation? Obviously, they must be the eigenstates of observer C. This means that instruments A, B, and C must be considered simultaneously, meaning that instrument C always has an impact on instruments A and B. In this way, the reason why observer A's choice of instrument status appears to be correlated with B's choice of instrument is that C's instrument serves as a liaison between the two instruments.*"

[5,p102] As Karl Hess pointed out, the experimental verification of Bell's inequality involves the timing of optical signals between experimental instruments, and it is this relativistic timing convention that leads to the long-range correlation between experimental instruments. Karl Hess's hidden variable analysis is consistent with Jin Guantao's philosophical explanation of the Bell type experiment. According to the AB effect, the phase factor in quantum wavefunction also varies with changes in the experimental setup. For observable quantities in quantum mechanics, Jin Guantao's Bell type experimental analysis also supports local realism based on phase factors.

Regarding the issue of quantum gravity, Stephen Hawking hoped that the quantization of the gravitational field would help eliminate the singularity problem in general relativity. And Roger Penrose believes that instead of quantization of gravitational field, it is possible to gravitize quantum mechanics, which helps to use the non local energy distribution of the gravitational field to explain non local phenomena in quantum measurements; and the differences in Weyl curvatures between spacetime singularities automatically provide the symmetry breaking of all physical processes in the universe in evolutionary directions of the past and future. [22] If there is indeed a disturbance caused by an unknown factor that triggers quantum collapse (whether it is a gravitational effect or something else), then all particles will continuously interact with this disturbance (regardless of whether they are in a superposition state). In theory, these should be detectable. Researchers say that this interaction should be similar to Brownian motion. In 2020, a team in Italy used this germanium detector to test a collapse model (Diόs -Penrose model). After noise reduction, physics did not see any radiation. In a paper published in August 2022, the results of 2020 were confirmed and strengthened.[23]

Most scholars believe that quantum non locality phenomena are unrelated to the non locality of gravitational energy in general relativity.We believe that general relativity involves global acceleration transformations, and according to the principle of equivalence, global acceleration transformations result in non local energy distribution of the inertial- gravitational field.Quantum non local phenomena are generally discussed in inertial frames, and the gravitational collapse model of quantum wave packets involves radiation caused by particle acceleration. However, there have been no experiments to demonstrate the radiation effect of gravitational collapse of this wave function.Perhaps future theories of gravity will change quantum mechanics, but not in the current form envisioned by Roger Penrose.

In the exploration of quantum gravity, some physicists such as Rosenfeld believed that curved spacetime quantum field theory is an effective limit theory for quantum gravity based on the spacetime limits of quantum measurements.But logically speaking, the curved spacetime quantum field theory is not a complete and consistent theory of quantum gravity. Jin Guantao believes that space-time measurement should strictly adhere to Bridgman's operationalism philosophy: "*Space-time measurement is the link that connects all universally reproducible controlled experiments in the physical world*"[24,p348], "*Once the space-time measurements no longer correspond to controlled experiments in the physical world, the correspondence between symbol systems with dual structures and empirical structures in the physical world becomes virtual. That is to say, on the surface, we are studying the spacetime of the physical world, but in reality, we are only studying pure mathematics, but researchers cannot realize this.*"[24,p349] "*The authenticity of time and space as experience is the universal repeatability of their measurement. When space and time are smaller than the Planck scale, spacetime measurementsare no longer possible, and spacetime as an empirical reality no longer exists.*"[24,p375] In Jin Guantao's view, the Planck scale distinguishes virtual physics from real physics. Lee Smolin raised doubts about string theory in 'The Trouble with Physics', which involves the scientific philosophical question of how quantum gravity as a real physical model can become possible.[25]

Chinese physicist Guo Guangcan uses vacuum fluctuations in quantum field theory to understand non local phenomena: "*The background vacuum of the quantum world is filled with virtual particles and processes. Virtual particles do not carry any information, and virtual processes can occur instantaneously. This is the physical connotation of the ground state of the cosmic wave function, and also the source of all things in the universe. After the birth of physical particles, the cosmic wave function is in a certain excited state, and real particles are always accompanied by a background vacuum state. That is, the wave function of particles describes the overall process of real particles and the background vacuum, rather than isolated particles. This wave function is dispersed throughout the entire space, and there are no isolated particles that leave the background vacuum, which is the root of the nonlocality of the quantum world. Particles must be distributed in probability throughout the entire space.*"[26]

We believe that vacuum fluctuations can be seen as hidden variables in the external environment where the measuring instruments are located. The interface between the quantum system and the environment is artificially selected, and these arbitrariness create the quantum randomness of vacuum fluctuations. The selection of environmental interfaces is a part of the instrument setups. According to Jin Guantao's cybernetics model of quantum mechanics, we find the hidden variables of quantum non local phenomena still stem from the localized division of instruments and environment, and the infinite degree of freedom environment in the decoherence model is manifested as an ubiquitous ocean of quantum fluctuations. Jin Guantao believes that the

building of holistic philosophy is based on two fundamental premises [5,p330]:
"*1. Any phenomenon is conditional, which we call the condition of things. To understand a phenomenon and its necessary and sufficient conditions is to discover the general law of causality.*
2. Any existence is surrounded by internal and external uncertain interference, which we call the uncertainty background of the real world."

Starting from these two fundamental axioms that people often overlook, Jin Guantao deduced a refined system of holistic philosophy, successfully demonstrating the seemingly mysterious characteristics of the integrity, occurrence, growth, and aging of various organizations, including atomic and molecular structures, cells, biological organ systems, ecological systems, economic market systems, and social form structures. By adopting the perspective of internal steady states in control theory to understand quantum eigenstates and analyzing the development of quantum information technology through the extension of structural stability, we can more reliably foresee the future scenarios of quantum information technology.[27] Jin Guantao's philosophy, in the grand context of contemporary science and technology, constructed a systematic philosophy with Russell's philosophical style based on the problem scenarios of Kant's thought system, and for the first time achieved the axiomatic reconstruction of dialectical materialism.

Today, most of the secrets of quantum physics are still in chaos. The local space-time structure of quantum entanglement remains unclear, and in the first quantum revolution, the explorations of Einstein and others were shrouded in the Copenhagen fog. In the second quantum revolution triggered by quantum information, the fog of quantum non locality looms over the future development path of quantum physics. As Kant said, we are in the darkness, only imagination runs in the darkness and creates extraordinary things. We are waiting for the lightning of groundbreaking scientific discoveries to illuminate the path forward.

V. Discussion

There are various interpretations of quantum mechanics, the popular saying is as David Mermin said in *Physics Today*: "*If I were forced to sum up in one sentence what the Copenhagen interpretation says to me, it would be 'Shut up and calculate!'*"[28] The experimental verification of Bell's inequality won the Nobel Prize in Physics in 2022, undoubtedly injecting almost insane enthusiasm into quantum information technology. However, Rene Thom pointed out as early as 1983: "*Mathematics, with its traditional quantitative methods, can only play a multidisciplinary collaborative role in a small corner of reality (mechanics and physics) that directly relies on space-time geometry.……We also need a more flexible mathematics with less generativity and more qualitative characteristics.*" [29,p385] Rene Thom believed that the modern scientific spirit urgently feels the need to understand the internal regulatory mechanisms of stability in things. He also pointed out sharply that quantum mechanics demonstrated the magical effects of Mach spacetime at a distance, and Einstein demanded a return to a scientific attitude that had precise requirements for locality.[29,p159-165] In Thom's view, catastrophe theory is essentially a localized theory that can eliminate the non local, long-range, and quasi magical characteristics of concepts such as complexity, order, organization, information, and cryptogram.[29,p152-153] In quantum mechanics, the intrinsic wave function form that constitutes the dynamical system is structurally stable, and the energy state essentially depends on the topological properties of its configuration. The square of the quantum wave function not only has probabilistic properties, but also reflects the extreme curvature of the normalized hyper-surface. The entropy structure of thermodynamic systems can also be explained as being proportional to the total curvature of the dynamic field.[30] According to Rene Thom, quantum information not only has a representation of probability distribution, but also has the curvature and topological complexity of eigenfunctions.

With the experimental verification and theoretical debate of Bell's inequality, the philosophical discussion of quantum mechanics has deepened from the relationship between causality and chance to the relationship between locality and non locality. Exploring the compatibility between relativity and quantum physics not only helps to solve the renormalization problem in quantum field theory, but also guides us to explore the deep space-time geometry of quantum phenomena. Once we pass through the fog of quantum non locality, the dawn of a new quantum mechanics explanation that embodies the spirit of relativity will emerge. The unity of physics and the empirical effectiveness of mathematical methods in the field of engineering and technology are calling for a new scientific philosophy with a sound sense of reality, crystal clear logical consistency, and rich interpretability.

[References]

[1]. J.S.Bell, On the Einstein-Podolsky-Rosen paradox, Physics 1,1964 : 195-200.
[2]. Switzerland] Nicolas Gisin:'L'IMPENSABLE HASARD', The Simplified Chinese version was translated by Zhou Rongting, Shanghai: Shanghai Science and Technology Press,2016.
[3]. Karl Hess, Einstein was right! Pan Stanford Publishing Pte.Ltd,2015.
[4]. Karl Hess.Bell's theorem and instantaneous influences at a distance. Journal of Modern Physics,9,1573-1590,2018.
[5]. Jin Guantao, My Philosophy Study, Beijing: New Star Publisher, 2005.

[6]. De Raedt, H.A.Michielson,Karl Hess. The Photon identification loophole in EPRB experiments:Computer models with single-wing selection, Open Physics, 15, 713-733,2017. http://doi.org/10.1515/physics-2017-0085.
[7]. Joy Christian. Disproof of Bell's theorem,Brown Walker Press, Second edition, p84-92(2014).
[8]. Quantum concepts in space and time, Edited by R.Penrose and C.J.Ishanm, Oxford: Oxford University Press,1986.
[9]. Peter Holland, Quantum theory of Motion, Cambridge:Cambridge University 1995.
[10]. Probing the Meaning of Quantum Mechanics: Physical,Philosophical and Logical Perspectives, Proceeding of the Young Quantum Meetings CLEA,Vrije Universiteit Brussel, 8-9 October, 2009. World Scientific Publishing Co.Pte.Ltd,2014.
[11]. C.S.Unnikishnan. Quantum correlation from wave-particle unity and loality: Resolution of the EPR puzzle,.Annales la Fondation Louis de Brogile,Volume 25.No 3.2000,363-378.
[12]. Robert Colub, Steven K.Lamoreux, A retrospective review of Von Neumann's analysis of hidden variables in quantum mechanics, Academia Quantum,2024-08-26. http://doi.org/10.20935/AcadQuat7311.
[13]. Kip S. Thorne, Black Hole and Time Curve,Simplified Chinese version was translated by Li Yong, Changsha: Hunan Science and Technology Publishing House,213,2000.
[14]. Zhang Yongde, Quantum wisdom root, Beijing: Tsinghua University Press, 2011.
[15]. Richard Feynman, The strange theory of light and matter, The Simplified Chinese version was translated by Zhang Zhongjing, Beijing: commercial press,1994.
[16]. Jin Guantao, Liu Qingfeng, etc, Collection of Issues and Methods, Shanghai:Shanghai People's Publishing House,1986.
[17]. Mario Bunge, Chasing Reality, Toronto: University of Toronto Press,2006.
[18]. Mario Bunge, Philosophy of physics, D.Reidel Publishing Company,1973.
[19]. Peter Atkins, Galileo's Finger——The Ten Great Idear of Science, Oxford: Oxford University,2003.
[20]. T.G.R.Bower, Development in fancy,by W.H.Freeman and Company,1974:149.
[21]. Heinz von Foerster, "On Constructing a Reality", The Internal Reality, How Do We Know What We Know(Contribution to constructivism) W.W,Norton and Company, New York,1984.
[22]. Stephen Hawking and Roger Penrose, The Nature of Space and Time, Princeton: Princeton University Press,1996.
[23]. Donadi, S. et al. Underground test of gravity-related wave function collapse. Nature. Physics. 17, 2021:74-78 .
[24]. Jin Guantao, The real & the virtual, Beijing: CITIC Publishing Group, 2023.
[25]. Lee Smolin, The trouble with physics,Boston•New York: Houghton Mifflin Company,2007.
[26]. Guo Guangcan, Subversion: Embracing the Second Quantum Revolution, Beijing: Science Press,2022: 181-182.
[27]. Chris Jay Hoofnagle, Simson L.Garfinkel, Law and Policy for the Quantum Age,Cambridge: Cambridge University Press,2022.
[28]. David Mermin, What is it? Physics Today 42, 1989. doi: 10.1063/1.2810963.
[29]. Rene Thom, Mathematical Models of Morphogenesis, Ellis Horwood, 1983. The Simplified Chinese version translated by Zhou Zhongliang, Shanghai: Shanghai translation publishing house, 1989.
[30]. Rene Thom, Structural stability and morphogenesis, translated from French edition by D.H.Fowler, W.A.Benjamin, Inc, 1975:137-140.