A New Interpretation on Quantum Mechanics

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Based on new experiments about the “macroscopic Schrodinger’s cat state” etc., a self-consistent interpretation on quantum mechanics is presented from the new point of view combining physics, philosophy and mathematics together.

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I. INTRODUCTION

Quantum mechanics was established in 1925. However, in 1964, in his lecture at Cornell University, the famous physicist Feynman said: “There was a time when the newspapers said that only twelve men understood the theory of relativity. I do not believe there ever was such a time. . . . On the other hand, I think I can safely say that nobody understands quantum mechanics. . . . Do not keep saying to yourself, if you can possibly avoid it, ‘But how can it be like that?’ because you will get ‘down the drain’, into a blind alley from which nobody has yet escaped. Nobody knows how it can be like that.” [1][2].

Why quantum mechanics is so difficult to understand? Let’s look at a conceptual experiment proposed by Schrodinger in 1935 (see e.g.[2] [3]): A cat is confined in a closed box and staying in a quantum (coherent) state described by the wavefunction:

\[
\psi(x,t) = \psi_0(x,t) + \psi_1(x,t), \tag{1}
\]

Here \(\psi_0\) and \(\psi_1\) denote the “dead cat” and “alive cat” states respectively with \(x\) and \(t\) being the space and time coordinates. Once when we open the box to observe, a process of so-called “the collapsing of wave-packet” occurs suddenly. The probability of discovering the cat being dead (or alive) would be proportional to \(|\psi_0|^2\) (or \(|\psi_1|^2\)). Such kind of way of saying sounds absurd and so is named a paradox, aiming at rendering the contradiction contained in the theory more acute. It might be helpful to clarifying what’s wrong in the basic concept? The “cat paradox” raised by Schrodinger at least posed the following four questions in front of all physicists in a very acute way:

1. Is the Born statistical interpretation of quantum mechanics correct?
2. Is this probability interpretation valid for single system (a pure state, e.g. an electron or a cat)? Or we need an average over many systems under the same conditions (so-called the ensemble).
3. Is it suitable to describe a macroscopic living-being like a cat by the wavefunction of quantum mechanics?
4. If the cat is shrinking into a small one such that it can be described by the wavefunction \(\psi_0\), is it suitable to talk about \(\psi_0\) and \(\psi_1\) as two dead and alive cat states respectively?

II. EXPERIMENTS ON SCHRODINGER’S CAT STATE

After research for more than 70 years, the Born statistical interpretation has been verified by numerous scattering and decay experiments and it is valid even for single system. However, some subtlety in the probability interpretation was often overlooked (see below). The answer to the third question could be conjectured quite early: Only an object within the “quantum coherent length” can be described by the wavefunction , it is impossible for a large living-being like a real cat. The theoretical research in 1980s revealed that the principal factor limiting the coherent length of a quantum system is the “decoherence” effect induced by the coupling between the system and its environment. In recent years, the microscopic (atomic scale) and mesoscopic (in nm scale) Schrodinger’s cat states have been realized successively in various experiments.

In an experiment published in January 2000[4], Myatt et al. manufactured delicately the environment of single \(^9\)Be\(^+\) ion (the microscopic Schrodinger’s cat state) captured in an ion trap and observed the process of decoherence, i.e., the process of how the “cat” is killed during its interaction with environment. In July 2000, Friedman et al. prepared a ring of superconducting-quantum-interference-device (SQUID) under the magnetic field at low temperature[5]. Then the superconducting state inside the ring can be described by Eq. (1). It was stressed that \(\psi_0\) and \(\psi_1\) denote two states with clockwise and counterclockwise currents respectively and they differ in current 2-3 m\(\mu\)A, corresponding to the motion of \(10^9\) electron (Cooper) pairs in opposite directions (Here the coordinate \(x\) in Eq. (1) represents the magnetic flux inside the ring). Since \(10^9\) is a large number, the above experiment for the first time realized the thought experiment of Schrodinger’s in a truly macroscopic scale with \(\psi_0\) and \(\psi_1\) as the simulation of dead-and-alive cat.

Although \(\psi_0\) and \(\psi_1\) are two distinct states and if \(|\psi_1| > |\psi_0|\), there is only counter clockwise supercon-
ducting current superficially, the microwave absorption experiment [5] does verify the existence of $\psi_0$ as shown by the absorption probability which is proportional to $|\psi_0|^2$. On the contrary, if $|\psi_0| > |\psi_1|$, there is only clockwise current superficially, the existence of $\psi_1$ is also verified by experiments. When $|\psi_0| = |\psi_1|$, there is no current superficially, but the experimental analysis does show that two directions of current exhibit their existence with equal probabilities. All experimental results are in conformity with the calculation of quantum mechanics.

In the same issue of Nature journal, a theorist Blatter wrote a paper titled “Schrödinger’s cat is now fat” to explain the experiment [6]. And some articles were published on the famous media like New York Times to introduce the new experiment. In some caricature an alive cat with dead cat as its overlapping shadow was even larger than a man and so attracted strong interests in the public. However, “there is dead-cat inside the alive-cat” or “there is alive-cat inside the dead-cat”, do you believe in it?

III. WHERE IS THE PROBLEM?

Just like some problem in other field, once the contradiction becomes more acute, we are more near to the solution for the problem. Now the cat becomes bigger and bigger whereas quantum mechanics works better and better. To our understanding, new experiments are just further verifying that the cat is nothing but an “illusion” existing only in our brain which in turn proves that our interpretation on quantum mechanics was incorrect in the sense that the “quantum state” and “wavefunction” were understood too “materialized” in the past. Hence in our opinion, the “cat paradox” is now basically over [7].

Let’s consider a concrete example. A big company is controlled by two stockholders A and B. While holding stocks up to 51%, A has the management idea to run the enterprise “eastward”. On the contrary, B who holds stocks up to 49% claims that the enterprise should go “westward”. Then the board of directors passes a resolution to follow A’s opinion that the whole enterprise should carry out the management policy running “eastward”. Despite 49% of all staff members being reluctant to do so, all members are uniform in their faces. Alternatively, if due to some abrupt change, the stocks held by B rise to 51% while that by A drop to 49%, then all staff members go “westward” immediately.

The above example reveals that the dispute in management idea is a kind of hidden “contradiction” which is inevitable in a unified enterprise. But it does not exhibit itself as two kinds of management action in opposite directions explicitly at the same time. Notice further that the opinion itself of each side is also a “contradiction”, because every reasonable thought must be a unity of opposites. This is one of the most precious wisdom we have inherited from the philosophy for thousand years. Now Eq. (1) shows quite the similar thing. When $|\psi| > |\psi_0|$, to talk about that $\psi_0$ describes a hidden clockwise current is incorrect in the sense of an implicit (virtual) thing (like “idea”) being regarded as some explicit (real) thing (like “action”). In fact, a condition of $|\psi_0| > |\psi_1|$ is needed before $\psi_0$ can exhibit itself as a real clockwise current, but meanwhile, $\psi_1$ will then turn from explicit into implicit at once.

The above comparison tells us that, just like the “management idea” to some extent, the wavefunction as shown by Eq. (1) is by no means a visible substance but an invisible “contradiction field”. This is why in quantum mechanics one should write down a wavefunction, say a plane wave, in the following form:

$$\psi_p(x, t) = \exp[i(px - Et)/\hbar]$$

$$= \cos(kx - \omega t) + isin(kx - \omega t),$$

(2)

where $p = \hbar k$, $E = \hbar \omega$. Here an imaginary number unit $i = \sqrt{(-1)}$ is introduced such that its invisibility becomes obvious. Meanwhile, two parts (both of them are real and represent the observable plane wave in classical physics) separated by $i$ just represent two sides of the opposites in a contradiction field. (see below, also [8]). If we simply express the wavefunction in Eq. (1) by $\psi_p$ in Eq. (2), yielding:

$$\psi = C_0\psi_p + C_1\psi_{-p},$$

(3)

Then we see immediately that when $C_0 > C_1$, only clockwise current exists whereas only counterclockwise current exists when $C_1 > C_0$. Such kind of calculation can be performed by everyone who had learnt quantum mechanics and we all know that the wavefunction is an unobservable quantity. However, the puzzle is rooted at even deeper level.

Let us inquire of what is the meaning of $\psi_p$ in Eq. (2)? The explanation of many text books in physics (including that written by me) is as follows. It describes the motion of a free particle with energy $E$, momentum $p$ and $|\psi_p(x, t)|^2$ denotes the probability of “appearance of” the particle in point $x$ at time $t$.

Now I know I was wrong in the past. First, we had misunderstood the statistical interpretation by Born in 1926. Now we have to correct the words “appearance of” into “measurement on”. When we said “appearance”, we were tacitly assuming that the particle is a “point-particle” which moves to $x$ at time $t$ and then one might think “naturally” that the Born statistical interpretation is equivalent to “ensemble” interpretation. Next, $x$, $p$ and $E$ are all “information” about a particle and the majority of physicists (including Einstein) considered that these information are existing objectively, i.e., they exist already before the measurement is made. The Copenhagen school led by Bohr and Heisenberg had different point of view, they emphasized the repulsive property between the measurements of $x$ and $p$. Hence an uncertainty relation emerges as:

$$\Delta x \Delta p \geq \hbar/2,$$

(4)
But they also cognized tacitly that the measurement is still a reflection process. So they understood Eq. (4) as a “disturbance” of $p$ measurement on $x$ measurement or vice versa.

Now our point of view is the following: First, to think about a microscopic particle (say an electron) as a point-particle is groundless in experiments. According to various Schrodinger’s cat experiments, the electron diffraction (double-slit) experiment and the “which-way” experiment of atomic beam performed in 1998[9] (see also [3]), we prefer to say that a particle has no fixed spatial extension and form. The electron in a hydrogen atom is as big as the atom. And it could pass through the double-slit at a same time in diffraction (see section V). Second, a measurement is bound to change the status of an object and there is no any information existing before the change of object-status does occur. Hence the gain of information is not a process of reflection but an outcome of the changing-process. In other words, the information is created by the subject (via apparatuses) and the object in common.

The measurement is always an operation method (i.e., means) denoted by $A$ for changing the object and picking out corresponding data $a$: $A \rightarrow a$ (see Fig. 1). Similarly, another changing means $B$ leads to $b$: $B \rightarrow b$. If $A$ and $B$ are not in conformity but are imposed simultaneously on an object, then $A$ ($B$) would become the disturbance to $b$($a$). Hence we see that Copenhagen school had confused the concept of “changing” and that of “disturbance”. The changing is a necessity of getting the information, but it shows up as a disturbance to other information at the same time. This is the exact meaning of Eq. (4), see [3].

![FIG. 1: The measurement A(B) being an operation (denoted by the arrow) imposes on the object (denoted by oval rectangle), creating the data a(b). If A is not in conformity with B, then A(B) becomes the disturbance to b(a) as denoted by the dashed line.](image)

Actually, different points of view are subjected to most stringent test so far in the “which-way” experiment [9]. Since the which-way information is got from the internal state instead of the impact of photon on the atom, the quantum coherence of atom’s center-of mass motion has not been destroyed. As no momentum transfer is measured, the information about momentum $p$ itself does not exist at all, so does the relation (4). We need not worry about something which has not emerged yet[3].

To further clarify the above point of view, we need a broad survey on philosophy.

### IV. PHILOSOPHERS’ WAY OF SAYING

In ancient China, there was a saying in “The Book of Rites-University” edited by Confucius (551BC-479BC): To gain knowledge via ‘gewu’, the knowledge comes only after the “wui”(object) is “ge”. The words “gewu” was interpreted by the philosopher Cheng Yi (1033-1107, in Song dynasty) as “reaching the object” while Zhu Xi (1130-1200) explained it as “touching the object”. In Ming dynasty, Wang Shou-ren (1472-1528) interpreted it as “seeing the object” and Wang Gen (1483-1540) explained it as “the measurement on the object”, yielding a considerable progress (see [10]). It was not until Mao Zedong (1893-1976) in his article “on Practice”, a principle of “the cognition being stemming from the changing” was stressed, implying that “gewu” is now interpreted as some “changing process” (“biange” in Chinese, for further explanation, see section VII). It seems just appropriate. Just looking at the experimental methods in modern physics evolving more and more abundant, the energy being raised higher and higher, new phenomena and new particles emerge successively, we have been convinced that the replacement of the “reflection theory” by the “changing theory” in the epistemology of philosophy is indeed a big progress, a jump in conception.

In philosophy, one swam upstream from the epistemology to the “ontology”—the inquiry about the nature of universe and the origin of matters. It seems to us no surprise that in conformity with the principle in epistemology that “the information is generated from the changing process”, the “noumenon” does not contain information. There were various pronouns for the noumenon in Chinese philosophy, e.g., “emptiness(void)” or “oneness”. Sometimes, it was called the “Tao” (which means the “way” or “law”, see [10,11]). Lao Tze (who lived in the same time with Confucius, maybe a little earlier) said: “The Tao that can be expressed is not the eternal Tao. The name that can be named is not the permanent name”. In our understanding, his saying implies that the fundamental (eternal or perpetual) law cannot be expressed in words and the permanent name in wholeness (or totality) cannot be divided and put into various categories. Actually, similar point of view was prevailing in the Eastern philosophy, e.g., in the doctrine of Indian Hinduism or Buddhism[11]. But it seems to us that a deep philosophy without explicit saying is also a philosophy difficult to develope in real life. Lao Tze was wise to say more. He said: “the measurement one and one generates two...”. Then after common efforts of many philosophers, especially Wang Chong (27-100), Zhang Zai (1020-1077) and Wang Fuzhi (1619-1692), the theory of “yuanqi (the primary gas)” was developed. They claimed that all matters are generated from “yuanqi”, inside which there are two opposites named “yin and yang”. It is the interaction and mutual transform between yin and yang that...
are responsible for the motion and change of everything in the world. This is really a deep and flexible “ontology”[10,11].

In our opinion, to understand quantum mechanics at a deeper level, we have to deal with “yuanqi” which was later called the “Ether” in the Western philosophy or the “vacuum” in modern physics[3,8,11]. A particle is the excitation state of “yuanqi”, so its wavefunction has two parts—the real and imaginary parts which are exactly the mathematical expression of yin and yang as shown in Eq. (2). Hence the coordinate $x$ in the wavefunction must be the flowing coordinate of the “field” rather than that of the “particle”. After fixing $x$ (or $t$) in Eq. (2), we see the growth and decline of yin and yang complementarily and periodically with the evolution of $t$ (or $x$). Notice further that the difference between yin and yang is merely relative. At any time (or place) we can perform a phase (i.e., gauge) transformation: $\psi \rightarrow \exp(i\theta)\psi = \psi'$, and see that yin (or yang) transforming immediately to its opposite yang (or yin), in which the property $i^2 = -1$ plays a subtle role. Moreover, as the counterpart of Eq. (2) which describes a particle, the wavefunction of its antiparticle is only different in the substitution of $i$ by $(-i)$[8,3].

Now we turn to the Western philosophy. In the ancient Greek Philosophy, one school represented by Heraclitus (504BC) could be viewed as the counterpart of Chinese philosophers like Lao Tze and Chuang Tze (369BC-286BC) [12]. But another two schools had much more influence. One was the school represented by Pythagoras (580BC), Plato (428 BC) and Aristotle (384BC-322BC) who all emphasized numbers and mathematics. Another one school represented by Demokritos (460BC-370BC) claimed the atomism. The philosophy of these two schools had played an active role in promoting the development of modern science. Therefore, quite naturally, physicists could make careless mistake to think about the $x$ in a wavefunction as the spatial coordinate of some “point-particle”.

Beginning from Descartes (1596-1650), modern Western philosophers turned their emphasis from the “ontology” to the “epistemology”. They began to search for deeply the relationship between “being” and “thinking”, i.e., that between the “object” and the “subject”. Here we wish to stress an important idea of Kant (1724-1804). He persisted in separating so-called “thing-in-itself” (or “things-in-themselves”) from “phenomena”[13]. The former is existing objectively with no representation, i.e., we (subject) have no knowledge of it. When the same thing exhibits itself as a phenomenon, it turns to “thing-for-us”, i.e., a thing sensible to the subject. Kant’s doctrine about “thing-in-itself” was criticized by some philosophers and was often regarded as an “idealist” or “agnostic”. But actually, the development of science has been proving that Kant is right. As for the point that “thing-in-itself contains no knowledge”, Kant’s philosophy reached the same goal by different routes with the Eastern philosophy.

V. WAVEFUNCTION IS THE PROBABILITY AMPLITUDE OF FICTITIOUS MEASUREMENT

It’s not the time of Einstein and Bohr, many physicists don’t pay enough attention to the philosophy, they even think that philosophy has nothing to do with their researches. However, the situation is quite the opposite. In a general way, everyone (let alone a scientist) cannot detached from the philosophy. The problem is: Are you absorbing nutritions from the whole treasure-house of human being culture in a conscious manner? Or you might be confined to some way of philosophical thinking while not be aware of. In the specific sense of quantum mechanics, a series of experimental and theoretical researches for over 70 years have been making unique contribution to the development of philosophy. For instance, in 1935, the paper titled “Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?” by Einstein, Podolsky and Rosen[14] not only initiated a very important research field in physics called the EPR paradox[3], but also raised a proposition in philosophy that “what is the physical reality?”

Based on a series of experiments in recent decades, e.g., the two-photon EPR experiment, physicists have been cognizing the strange entanglement phenomena in a system composed of two or more particles. For instance, if Alice measured a photon being $x$-polarized, then Bob at far apart must measured another photon being $y$-polarized at the same time. It is a general feature of quantum nonlocality and denies definitely the so-called “local reality principle” proposed by Einstein. Besides, a beautiful EPR experiment on $K^0\overline{K^0}$ system [15] together with its theoretical interpretation [16] verified further that there must be antiparticle existing in quantum mechanics and its wavefunction is merely different from that of particle in their opposite signs of phase. Therefore, in our opinion, the EPR question as a “paradox” is now basically over too.

I have been thinking about a diagram which could answer EPR’s question from the viewpoint combining both quantum mechanics and philosophy. After meditation for years, a diagram came to me in an early morning as shown in Fig. [3].

In the upper part of Fig. [3], the epistemology and ontology are combined to stress that it is the measurement, i.e., the process of changing, which realizes the transform from “thing-in-itself” to “thing-for-us”. The lower part shows how quantum mechanics works. First, we divide from “things-in-themselves” a system which is prepared to be studied by means of boundary conditions and denote it by a quantum state (a $|\psi>$ vector in the Hilbert space as introduced by Dirac). It has no representation and so no coordinate $x$ even no time $t$ in the Heisenberg picture (exactly coinciding with Kant’s thinking). Next, in accordance with the phenomenon we are going to observe, we choose an “ideal apparatus” denoted by $|x, t>$ for measuring the quantity $x$ (say, the position of a particle). Then a wavefunction in the corresponding $x$
representation can be written down as:

\[ \psi(x, t) = \langle x, t | \psi \rangle \]  

which is the “projection” (also called the contraction or scalar product) of a “quantum state vector” \( |\psi\rangle \) onto the “coordinate basis vector” \( |x, t\rangle \).

We claim that a wavefunction is the probability amplitude of fictitious measurement with the following explanation.

(a) This measurement is fictitious theoretically and not a realistic one. So it does not destroy the coherence of quantum state. For a same quantum state, we may write down several wavefunctions in different representations at the same time.

(b) A wavefunction in certain representation obtained via the fictitious measurement reflects the existence of particle in the form of “contradiction field” at each point of the representation space. This kind of fictitious reflection is quite flexible. For example, in nonrelativistic quantum mechanics, the wavefunction describing a stationary motion of particle displays precisely the contradiction equilibrium state reached via interactions between the particle and its environment. In this case the energy \( E \) of the particle contains merely the kinetic energy and potential energy. On the other hand, in relativistic quantum mechanics, \( E \) must includes the rest energy which becomes more important. So the wavefunction will reflect the stronger (principal) contradiction field inside the particle while still keep the meaning of contradiction field of the particle with its environment [3].

(c) Let’s discuss the double-slit diffraction of electrons as an example (for apparatus, see [1,2,3]). Before an electron is detected by the detector on the screen at right-side, its wavefunction at the right-side of double-slit (which is just the boundary condition in present problem) is expressed as a linear superposition of two spherical waves delivered from slit 1 and slit 2 respectively:

\[ \psi(x, t) = \psi_1(x, t) + \psi_2(x, t) \]  

In the expression:

\[ |\psi(x, t)|^2 = |\psi_1(x, t)|^2 + |\psi_2(x, t)|^2 + 2Re[\psi_1^*(x, t)\psi_2(x, t)]. \]  

the third term at right-side is named the “interference term” which is varying at various points on the screen to be either positive or negative.

The electron beam density can be lowered to very weak level in experiments, say, there is only one electron impacting at one point on the screen per second. Nonetheless, after a long duration, interference fringes are displayed on the screen and can be interpreted by Eq. [5].

It was thought being too incredible because a proposition was raised in the past that (see [1], p.139) “either an electron goes through slit 1 or it goes through slit 2” whereas the explanation of interference requires two waves coming from both slits (as shown by the third term in Eq. [5]). Hence a conceptual “paradox” was inevitable that “the electron is a particle but also a wave at the same time”.

As discussed by Feynman [1], an electron, before it is detected, can only be described by the wavefunction, which spreads all over the space around the double-slit. Thus the above proposition itself is meaningless. (We ask our readers to notice that instead of choosing one answer from two possibilities destined by the proposition, we just negate the proposition itself. Similar attitude will be adopted when other paradoxes in quantum mechanics are dealt with, see [3]).

Once an electron is captured by an atom (in the detector), they will form a new quantum correlated state. In other words, when an electron is detected at certain point \( x \), it exhibits itself as a real transform (transmutation) process of contradictions, which renders the “contradiction field” at other points (describing the fictitious interaction between the electron and its environment) suddenly disappearing. It is the meaning of so-called “collapsing” of wavefunction toward the \( x \) point.

Because of nonlocality (spatial extension) of an electron, also due to infinite degrees of freedom in interactions between an electron and the screen (detector), they
havent’t been and are impossible to be expressed in the Hamiltonian and boundary conditions, which atom on the screen will “seize” the electron is an event of probability. What the wavefunction can tell us is a kind of potential possibility of contradiction transform at point x. Just like other field in physics, the strength of contradiction field is proportional to its amplitude. So $|\psi(x, t)|^2$ represents the real probability of detecting the electron at point x. The above probability interpretation is different from the “ensemble interpretation” based on “point-particle”. The classical concept of “ensemble” cannot reflect the subtlety of quantum probability unveiled in experiments on single electron, ion or atom, let alone the strange entanglement in quantum system compose of two or more particles (where the concrete correlation form is the outcome of measurement). We appreciate very much the saying by Herbert[17]. He called the wavefunction a “possibility wave” and wrote down an interesting formula:

$$\text{probability} = (\text{possibility})^2. \quad (8)$$

For further clarity, we suggest that one more word could be added to both sides respectively as follows;

$$|\psi|^2 = \text{real probability} = (\text{potential possibility})^2. \quad (9)$$

We stress again that the reason why ψ denotes the potential possibility is because it, being a “contradiction field”, reflects the interaction between a “fictitious apparatus” and the object. Hence ψ is something “half-real but half-virtual” and is located between the “thing-in-itself” and the phenomenon, it is a reflection of the existence state of an object in our cognition. The introduction of wavefunction is undoubtedly one of the greatest innovations in the human history, also an epoch-making discovery in physics—a discovery that the essence of everything turns out to be contradictions rather than some indivisible point-particles.

(d) Being a fictitious contradiction field, the wavefunction can be superposed linearly and obeys the linear Schrödinger equation, showing that wave motion is invisible and reversible. But once when a particle is measured, implying that a realistic transform process occurs among contradictions, the particle property exhibits itself immediately. The corresponding particle creation (and/or) annihilation operators obey the Heisenberg (Fock) motion equation which is nonlinear in general, showing that only during the real transform process can contradictions be visible—they cease to be linearly superposed and become exclusive each other and irreversible. Hence, the so-called “wave-particle duality” is by no means a “paradox” at the same level but in conformity with the feature of particle being contradiction field.

(e) The concepts about position (x), momentum (p) and energy (E) etc. which should be derived originally from measurements via the analysis and induction method are now introduced into the theoretical deduction process in advance by means of wavefunction which is a contradiction field describing the interaction of fictitious apparatus with the object. Then using the dynamical equation (Schrödinger equation, Dirac equation, etc), one will be able to predict what observables with their probabilities of occurrence will appear in a real measurement. This should be viewed as a fusion and development at higher level of analysis—induction method and deduction method which are originally separated in the history. The fusion of these two methods makes quantum mechanics a scientific theory of contradictions which can be calculated quantitatively, so it brings the human’s subjective activity into full play in cognizing the objective world.

VI. MATHMATICIANS’ WAY OF SAYING

To study quantum mechanics, one has to learn contemporary mathematics (topology, etc.). But it was too difficult to me. Just like what described by Prof. C.N.Yang, facing a book of this kind, I couldn’t read further after reading one page. Sometimes, I even couldn’t read further after reading one line. Why formulas are much less than words in mathematical books? Why there is no subscript under an English letter in these formulas? I wondered for many years before I realized eventually that it is because mathematicians pay more and more attention to separate the objective existence from its representation rigorously.

Let’s look at a familiar vector V, it merely denotes a “geometrical object” having a direction in the space. No any number is involved. To endow it with some concrete representation, mathematicians introduce a coordinate-system (in two-dimensional space in Fig. 3 as an example) and project V onto the coordinate axes, yielding $v_x$ and $v_y$. The latter are then the concrete representation of V. In rigorous notation, they read:

$$v_x = e_x \cdot V, \quad v_y = e_y \cdot V. \quad (10)$$

where $e_x$ and $e_y$ are unit vectors along the x and y axes. We should notice the resemblance between Eq. (10) and Eq. (3).

Furthermore, in contemporary mathematics, a vector field continuously spreading over the space, such as the vector potential field $A(x, t)$ of electromagnetic field in physics, is needed to be discussed. Because not only the components of $A(A_x, A_y)$ are depending on the coordinate-system, but A is a function of x as well, mathematicians innovate a very elegant notation like A to express that:

$$A = A_\mu dx_\mu = A_x dx + A_y dy = A'_x dx' + A'_y dy'. \quad (11)$$

Here A is expanded by its components while the coordinate differentials $dx_\mu$ are written together. Such kind of form is called the “connection one-form”. It is actually the counterpart or development of the notation for single
FIG. 3: The concrete representation $v_x$ and $v_y$ of an abstract vector $V$ (in two-dimensional space) are contractions (scalar product or projection) of $V$ with the unit vectors of coordinate-system, $e_x$ and $e_y$.

The common feature of Eqs. (11) and (12) is that the “geometrical object” at the left-side is linked to its concrete representation via the coordinate-system. Thus a fact is stressed that the existence of a geometrical object is independent of the subjective choice among various coordinate-systems whereas its representations are taken in different concrete forms with respect to different coordinate-systems.

I would like to tell a small story I heard it myself. Once a time, the famous mathematician, Prof. S-S Chern delivered a lecture on contemporary differential geometry in Nankai University. When he wrote down a letter to, among those present was Prof. C.N. Yang who suddenly got an inspiration and wrote down as follows:

$$\psi > |x, t| \psi >$$

The conversation between Profs. Yang and Chern revealed that actually mathematicians are not so different from physicists when they think about some problem and begin to do the research. They nearly all begin “from the particular to the general”. However, once they write the book, their styles are widely different. It reflects a deep discrepancy between the “culture” of mathematics and that of physics. This discrepancy is often difficult to understand if not listening to the lecture personally and exchanging the point of view thoroughly. (I wish to thank Prof. Yi-zhi Huang for discussing this problem with me via the phone-call many times.)

VII. PRINCIPLE OF RELATIVITY AND PRINCIPLE OF CHANGING IN EPISTEMOLOGY

All our discussions above are based on a “principle of relativity” in epistemology: When Einstein established the theory of special relativity, he taught us that one should not discuss the absolute motion, absolute space or absolute time. Rather, one should discuss the relative motion, relative space or relative time. In general, when one is talking about cognition, one must first put himself into the process of cognition as the “subject” and then survey the environment of the object under consideration. A thing can only be cognized during its motion and change relative to other things. If isolated from its opposites (i.e., its environment, including the subject and all measuring apparatuses), it merely exists abstractly and so is bound to become mysterious object devoid of any understanding.

In the Chinese classical novel titled “Dream of the Red Mansion” (by Cao Xue-qin, who told a story occurred in a big Jia’s family in Beijing during 1729-1737 in Qing dynasty), a young man Jia Baoyu was worried about Ms. Lin Daiyu who used to feel sad all day long. “I can’t understand her”, Baoyu thought. Until one day he suddenly got an inspiration and wrote down as follows:

You won’t be you if I wasn’t born.

One can’t understand her from her alone.

Therefore, to understand an abstract quantum state $|\psi >$ of a particle, one brings his subjective activity into full play by introducing a fictitious apparatus $|x, t >$, yielding the wavefunction $\psi(x, t) = \langle x, t | \psi >$ to reflect the “contradiction” due to the interaction between the particle and the fictitious apparatus for measuring $x$ ($x$ is not necessary a continuous spatial coordinate). By calculation of $\psi$, one can predict in advance what are potential observables and what are their probabilities of occurrence before the experiment is really made.

Similarly, to understand Daiyu, one has to survey her environment. Being a sensitive young lady, Daiyu was living in the global environment of Jia’s big family. If isolated from her relations with Baoyu, Baoyu’s grandmother, Ms. Wang Xi-feng and Ms. Xie Bao-cha, etc., i.e., if isolated from all realistic appearances of these relations and their contradiction analysis, Daiyu would be never understood why she was so sad.

After reading what Baoyu wrote, Daiyu, with Ms. Xue and Ms. Shi Xiangyun, went immediately to visit Baoyu for a conversation, aiming at learning what he was thinking at that time. But was it a simple “thought exchange or reflection”? No. Just at the instant their conversation began, everyone of them was changed once again and Daiyu was caught by a new suffering.

Hence, a measurement is by no means a process of “reflection”, but a process of changing (“biange”) the object by the subject. However, the sole English word “changing” is far from enough to express the deep connotation of Chinese words “biange”, which implies “penetrating deeply into the object and changing it at the root”. The root is nothing but “contradictions”. So the changing process is actually a process of transform (transmutation) between contradictions. In terms of newest terminology in quantum mechanics, during the measurement, a new quantum correlated state (entangled state) is es-
established between the apparatus and object. Meanwhile, the quantum (coherently) correlated state originally existing inside the object is destroyed. It is just during the process of destruction and reestablishment of the equilibrium state among contradictions, can some “information” be created and is sensible to the subject.

VIII. EPILOGUE

I learnt quantum mechanics in 1954 when Prof. Xie Xide was our teacher. Ever since, I have been involved in a strong feeling with quantum mechanics. I was so keen on it, so excited in it and sometimes even nervous as well. It was such a feeling just like being haunted by a cat in the dark. It was not until recent years that a series of new brilliant experiments showed up. The light suddenly flashed in front of us. I was pleasantly surprised and began to relax for a while. Then a poem came to my mind as follows:

Now the cat looks amazing.
Let’s listen to what she’s saying:
“People were surprised at the emperor’s clothes.
But he was wearing nothing.”

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