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Short Communication

Common sense and quantum mechanics

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Abstract

It is shown how changing only one word in the usual interpretation of quantum mechanics makes it possible to turn its puzzles and miracles into obvious trivialities

Introduction

About a hundred years have passed since the creation of Quantum Mechanics. Its mathematics allows us to confidently calculate the observed quantum phenomena. Until now, all its prescriptions have invariably been justified by experience, despite their apparent paradoxical nature in many cases. Due to this circumstance, QM always looked puzzling and mysterious.

Its development as a rigorous mathematical theory began with the work of Heisenberg [1], whose main idea was to use in a theory only measurable quantities.

He managed to carry out successfully this program with some simple examples. To his surprise, he discovered that in his theory observed physical quantities had two indices thus being the elements of a certain matrix. This way the Matrix Mechanics was born.

Then Schrödinger based on de Broglie's idea of particle-wave duality built Wave Mechanics as another version of QM [2]. Its essence was the introduction of wave functions as the solutions of the famous Schrödinger wave equation.

After some time Dirac built an elegant mathematical scheme for quantum calculations [3] where wave functions became the vectors of a functional Hilbert space while observable physical quantities were represented by the matrix elements of this space written in the form of $<bra|C|ket>$. The bracket corresponds to the matrix observable of Heisenberg $C\ (b,k)$ where the operator C represents a physical quantity, while ket stands for the wave function of Schrödinger and the bra is its complex conjugation. The bracket looks like an average of two random quantities with some weight.

Finally, these empirically found rules and principles of QM were systematized and interpreted by Bohr, Born and others which created the so-called Copenhagen Interpretation that later became canonical [3-8]. Its creators aimed to avoid all possible logical contradictions and they successfully reached this goal.

Note that the central element of the interpretation is not the Heisenberg observables or Dirac brackets, but the Schrödinger wave functions or Hilbert space vectors of Dirac.

Mysteries of quantum mechanics

Being logically irreproachable the Copenhagen interpretation nevertheless does not explain QM prescriptions in a way more or less compatible with our intuition based on everyday experience.

Its statements frequently look rather puzzling from such a point of view creating the impression that QM contradicts our usual common sense.

All QM books contain together rigorous and logical-mathematical parts of the description of a quantum object (quantum particle) that suspiciously reminds the description of the phlogiston and other "superfine matters" of past centuries [3-11].

One says that the quantum particle is not a wave and not a corpuscle nevertheless their properties. One add also that such objects (Eddington's "wavicles") are inconceivable to our human imagination.

Due to the lack of simple and natural explanations of seemingly strange quantum phenomena, the so-called mysteries and miracles arise together with numerous attempts to re-interpret [8] QM as well as the desire of most scientists not to touch this item at all, but to "calculate and not ask questions".

Banishing of mysteries

Dirac [3] rigorously and logically introduces the ket-vectors and the bra-vectors as well as the bracket = *<bra|C|ket>*. This bracket describes the physically observable quantities. It clearly shows that we need two quantities (bra and ket) for their adequate description. Unfortunately, Dirac concluded that in interpreting QM one can use the vector bra or the vector ket. This wrong or instead of right and (much better together) was the fatal error. Generally accepted it prevented the rational understanding of QM without mysteries since the adequate description of all observed QM phenomena only in the ket-language is impossible in principle.

It is the same as trying to march using only one leg. Below we show how the addition of the second leg makes marching quite easy.

We can imagine the potentially observed quantum object (wavicle) as a bra+ket pair in the bracket of any observable quantity. Being solutions of the Schrödinger equation bra and ket have phases so the bracket also has the phase as the difference between bra and ket phases.

Let us apply the bra+ket language to the famous dispute between Bohr and Schrödinger on the electron *stationary orbits* and *quantum jumps* [8]. They used the ket-language and came to nothing since both were right from their points of view. In the bra+ket language, the question becomes trivial: the bra+ket pair with the same quantum indices forms the potentially observed quantum particle (a wavicle with zero phases) of the time-independent stationary orbit while the bra+ket with different indices (a wavicle with oscillating phase) forms the quantum jump state oscillating in time. Since a perturbation changes the bra and ket of the stationary orbit separately in time the jump states arise naturally during the transitions between two stationary orbits. Generally, such states in a quantum system describe the time-dependent fluctuations over the constant background given by stationary orbits. Note that both types of quantum states are constructed from the same set of eigenfunctions of the Schrödinger equation so that Schrödinger had a reason to deny Bohr's quantum jumps in the ket-language.

The wavicle interference with itself (the main QM secret according to Feynman) also reduces to triviality: no interference occurs when the wavicle bra and ket go the same way (and form the phase-independent constant background on the screen). When they go different ways then they acquire a phase difference and produce phase-dependent wavicle. The wavicles with phase contribute to positive or negative fluctuations over the constant background which participate in constructive and destructive interference [12].

The mysterious EPR correlation can be easily understood without nonlocality and other strange inventions. The phenomenon requires two independent detectors and two also independent wavicles without phase.

Initially, each wavicle consists of bra and ket with the same (sign-opposite) arbitrary phases. When these initial wavicles hit the detectors they produce phase-independent values with no correlation between them.

However, the bra of one initial wavicle can hit the detector together with the ket of another wavicle or vice versa. These two new wavicles at the detectors have equal (but sign-opposite) phases and therefore by definition are phase-correlated.

They are just mysterious entangled quantum particles. Their contribution to the detector data vanishes after separate averaging but reemerges after joint averaging of detector data Since their phases cancel each other.

Note that such exchange-correlation requires no special procedure to get so-called entangled states. Also, all bra+ket pairs with different quantum indices do not form the particle number and therefore their contribution does not participate in the Bell inequality derivation [13,14].

Without perturbation, the phase correlation can survive over large time and space intervals. The phases of bra and ket can be considered as a sort of hidden variable of QM [15]. As a rule, they do not enter the QM final expressions, especially in secondary quantization mathematics.

All other puzzles and mysteries of QM evaporate when one uses the bra+ket language (more precisely, the bra+ket=wavicle physical picture).

Conclusion

The use of the bra+ket language for the interpretation of QM mathematical expressions permits getting simple and natural answers to several questions that" one cannot ask" in the usual (incomplete!) ket-language. Zero-phase wavicles look like corpuscles and give the constant background of observable quantities while wavicles with phase give phase-dependent observable quantities which ensure the interference phenomena.

Note that during the evolution wavicles can lose or acquire phases since their bra and ket components move separately. Thus the same wavicle can reveal itself as a wave or as a corpuscle and such behavior is quite natural.

In the microscopic Quantum World, the bra and ket

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oscillations usually are too fast which prevents their observation as separate objects. But their combinations in the form of wavicles generally have much less oscillation frequencies (even zero) and therefore emerge in our Classical World as observed quantum particles which become classical objects.

Finally, let us emphasize that any adequate interpretation of QM mathematics is impossible without this natural physical picture and the bra+ket language. The use of incomplete ket-language inevitably leads to an impasse. The impasse obliges either to invent various non-physical fantasies grossly contradicting all established principles of Physics inherited from the past or to capitulate: "it is impossible to understand Quantum Mechanics".

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