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AS–ITP–92–36

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On the Einstein, Podolsky and Rosen Paradox and the Relevant Philosophical Problems

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(Received June 22, 1992)

Abstract

It is shown that the quantum mechanics is compatible with the objective realism. The conclusion, drawn by B. d'Espagnat, about the "quantum mechanics curiously diagrees with the doctrine that the world is independent of mind", is not convincing and this analysis contains logical loopholes. However, the realism should be taken as local, stochastical or statistical realism.

I. Introduction

The controversy on the " Can The Quantum Mechanical Description of Physical Reality be Considered Complete?" was everlasting for almost sixty years.[1,2] A clarification was made by J. Bell[3], who showed that any local, deterministic theory leads to a relation called the Bell's inequality, whereas the quantum mechanics violates the inequality. From 1972-1982, different kinds of experiments performed by experimentalists, gave results that indicated the violation of the Bell's inequality and were in agreement with quantum mechanics[4]. Thus the Bell inequality is violated now is generally accepted.

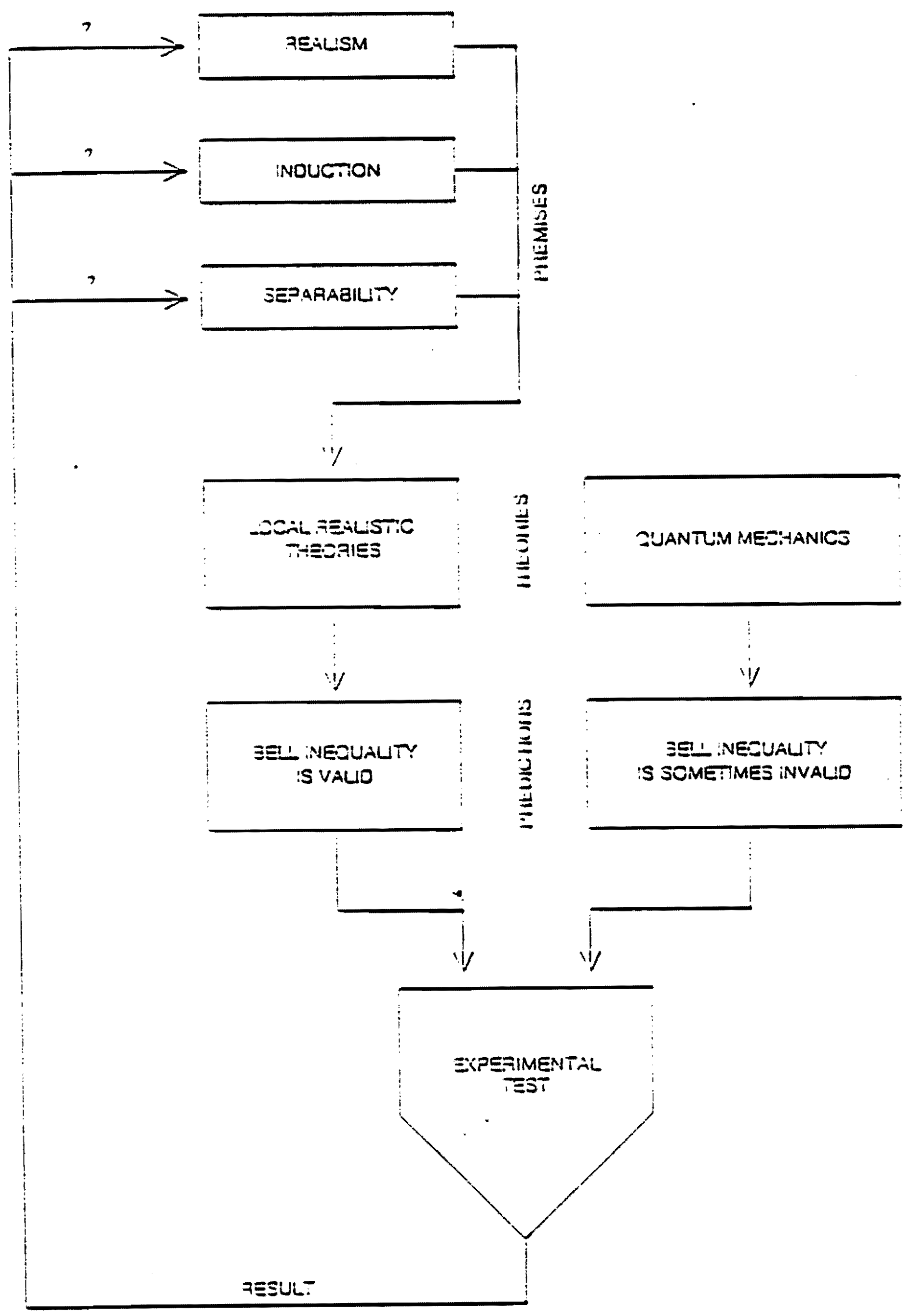
In 1979, B. d'Espagnat gave a detailed analysis on the philosophical problems pertinent to this topic. Finally, he drew the conclusion, the doctrine that the world is made up of objects whose existence is independent of human consciousness turns out to be in conflict with quantum mechanics and with facts established by experiment."[5] Similiarly N.D. Mermin gave an alternative representation of this point of view, "we now know that the moon is demonstrably not there when nobody looks".[6]

Are their conclusions wrong or correct?

II. d' Espagnat's Arguments

B. d' Espagnats' arguments can be expressed by the following sketch, which is taken from

"The Quantum Theory and Reality" [5].



He showed that a local realistic theories is originating from the three premises: " One is realism, the doctrine that regularities in observed phenomena are caused by some physical reality whose existence is independent of human observers. The second premise holds that inductive inference is a valid mode of reasoning and can be applied freely, so that legitimate conclusions can be drawn from consistent observations. The third premise is called Einstein seperability or Einstein locality and it states that no influence of any kind can propagate faster than the speed of light" [5].

In short, these premises can be identified as: 1) realism, 2) the free use of induction and 3) seperalibity.

Since the logical consequence of the local realistic theory is the Bells inequality, and there is strong experimental evidence that the inequality is violated, thus, at least one of the three premises of local realistic theories must be false.

d' Espagnat argued, that 1) "in a physics experiment, the seperability assumption expressed the intuitively reasonable idea that the spin components of one proton have no influence over these of the other proton, provided the two particles are far apart, $\cdots$ this assumption must now be regarded as highly questionable"[7]. 2) If unbiased and large amout of samples were tested, " the confidence of these assertions approaches certainty as the size of the sample increases"[7]. Hence, he leads to the conclusion: the "quantum mechanics curiously disagrees with the doctrine that the world is independent of mind".

III d' Espagnat's loophole

However, if we examine the proof of Bell's inequality more carefully, the assumption of realism really is one of the premises of a local realistic theory, but this premise is only a *special form* of realism, the deterministic realism, i.e. the existence of hidden parameter. So that, the violation of Bell's inequality can not be regarded as a violation of realism *in general*, e.g. a general statement, such as " disagreeing with the doctrine that the world is independent of mind"!

IV. Realism is one of the premises of quantum mechanics

In the history of philosophy, there were different definitions about realism. What we shall adopt, is

Realism =the existence of world is independent of mind.

In order to show that the realism is one of the premises of the quantum mechanics also, we shall analyze the following example, the spin correlation of a pair of electrons or protons, in detail.

i) Assume we have some composite system, composed of the electrons or protons A and B, with the total angular momentum equal to zero.

ii) The spin correlation function $E(\vec{a},\vec{b})$ is defined as

$$E(\vec{a},\vec{b}) \equiv 4\overline{A_a \cdot B_b}\,, \tag{1}$$

where A_a and B_b are the spin component of particles A and B along the direction of unit vectors $\vec{a}$ and $\vec{b}$.

iii) According to quantum mechanics, one easily shows, that

$$E(\vec{a},\vec{b}) = \langle 0^+|\vec{\sigma}_A \cdot \vec{a}\ \vec{\sigma}_B \cdot \vec{b}|0^+\rangle\,, \tag{2}$$

in which $\vec{\sigma}_A$ and $\vec{\sigma}_B$ are the Pauli spin operators of the particles A and B respectively, and the wave function $|0^+\rangle$ is

$$|0^+\rangle = \frac{1}{\sqrt{2}}(\psi_{+\frac{1}{2}}(A)\psi_{-\frac{1}{2}}(B) - \psi_{-\frac{1}{2}}(A)\psi_{+\frac{1}{2}}(B)) \tag{3}$$

the c_i is the coefficient of expansion of the wave packet $\psi(x)$ in the basis of the eigenfunction $\psi_i(x)$, i.e.

$$\psi(x) = \sum_i c_i \psi_i(x) , \tag{11}$$

The value of L_i can be measured and obtained by some apparatus, while the $|c_i|^2$ is the transition probability, i.e. the wave packet collapse to

$$\psi(x) \Longrightarrow \begin{cases} \psi_1(x) & & |c_1|^2 \\ \psi_2(x) & \text{with the transition} & |c_2|^2 \\ \vdots & \text{probability as} & \vdots \\ \psi_n(x) & & |c_n|^2 , \end{cases} \tag{12}$$

which can be measued by experiments also. This theorem of measurement clearly answers: even if the apparatus interfere the wave packet of the particles system, but this theorem still guarantees how the *real value* of physical quantity L of the *original quantum system* could be found!

It seems difficult to understand what is the essentiality of the collapse or the reduction of the wave packet. Actually, the collapse of the wave packet is a general phenomena occuring in any statistical measurement. For example, a "dice" will collapse to certain number, eg. the "red 4", when the "dice" hits on the table, while before this acting, all the number $1, 2, 3, \cdots, 6$ is indefinite, each of them has a probabilitily of 1/6. Although the table *disturbs* the *original* state of the "dice". it does not prevent the *objective* studing the probability of the appearance of the "red 4".

When we apply the same theorem to the process of the spin correlation measerement, the wave packet of this composite system

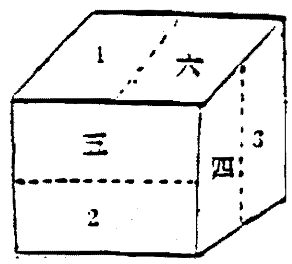
$$|0^+\rangle = \frac{1}{\sqrt{2}}\left(\psi_{+\frac{1}{2}}(A)\psi_{-\frac{1}{2}}(B) - \psi_{-\frac{1}{2}}(A)\psi_{+\frac{1}{2}}(B)\right)$$

will collapse to

$$\Longrightarrow \begin{cases} \psi_{+\frac{1}{2}}(A)\psi_{-\frac{1}{2}}(B) & & \left(\frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2} \\ & \text{with the transition} & \\ & \text{probability as} & \\ \psi_{-\frac{1}{2}}(A)\psi_{+\frac{1}{2}}(B) & & \left(-\frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2} \end{cases} \tag{13}$$

The peculiarity of the collapse of the wave function of this composite system, is that the eigenfunctions should be taken as the products of $\psi_{+\frac{1}{2}}(A)\psi_{-\frac{1}{2}}(B)$ and $\psi_{-\frac{1}{2}}(A)\psi_{+\frac{1}{2}}(B)$.

This process of measurement is like a special "dice" in the following form.



with the following law of conservation, i.e.

$$\text{Arabic No} + \text{Chinese No.} = \text{constant} = 7 \tag{14}$$

VI. On the mechanism of the collapse of the wave packet

Of course, the collapse of the wave function in quantum mechanics is different from the classical "dice", since the former is always accompany with "the disappearance of the interference". This had been explained, for instance, by a successiful theory of measurement, developed by A. Daneri, A. Loinger and G.M. prosperi in 1962[7]. The essentiality of this theory is that the detectors are made from certian thermodynamical quasi-stable systems, the collapse of the wave functions occurs during the interaction between the particles and the apparatus. It can be shown that the interference terms are multipied by some numerical factors practically zero, while the non-interference terms is multiplied by a factors 1, both of which originate from the variables, which describe the apparatus.

What is the role the apparatus play, i.e., the confirmation of the spin correlation of the quantum mechanical system, a reflection of the physical reality which is independent on the human consciousness.

VII. Conclusions

1) Quantum mechanics is compatible wich the objevtive realism i.e., the world is made up of objects, which is independent of human consciousness.

2) The deterministic realism is not supported by the experiments done in quantum mechanies. The realism of quantum mechanics should be interpreted as local and stochastical or statistical realism.

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