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ON THE MEANING OF BELL'S INEQUALITIES VIOLATION

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ABSTRACT

We relate the interpretation of "uncertainty" principle as "no joint localization principle", to Bell's inequalities violation by quanta.

I. Bell's Inequalities

Consider three series of experiments with correlated, polarized photons [2] :

I $\underset{R}{\boxed{H,V}}$ ←------- S -------→ $\underset{L}{\boxed{\phi_\pm}}$

II. $\underset{L}{\boxed{H,V}}$ ←------- S -------→ $\boxed{\Theta_\pm}$

III. $\underset{L}{\boxed{\phi_\pm}}$ ←------- S -------→ $\underset{R}{\boxed{\Theta_\pm}}$

Here "S" stands for the source of such photons, L stands for the left, while R for the right detector.

$\boxed{H,V}$ denotes a polarizer, that can state either horizontal (H) or vertical (V) polarization of one photon.

$\boxed{\phi_\pm}$ (similarily $\boxed{\Theta_\pm}$) denotes a device with two possibilities: either it states polarization of a photon along the direction making an angle ϕ to the horizontal (ϕ_+) or along the direction perpendicular to this very one, (ϕ_-). R and L devices are space-like separated. Measurements are carried out repeatedly in each series I,II,III with pairs of correlated photons.

This is to mean, that in the case of the situation

$$\boxed{H,V}_L \longleftarrow\text{------}\quad S \quad\text{------}\longrightarrow \boxed{H,V}_R$$

{an outcome "h" in L} is always accompanied by {an outcome "v" in R} , (same for v,h pair of outcomes).

Let us denote, [2], by $n(v,\phi_+)$ the number of pairs of the following outcomes:

{the outcome v in L} , {the outcome ϕ_+ in R} ,

for the series I, and correspondingly, we shall denote the same for II and III by: $n(v,\Theta_+)$ and $n(\phi_+,\Theta_+)$.

Assumption (A) :

Let us assume now, that knowledge of an outcome in L means a knowledge of the polarization of the right photon. Put it another words: one polarization of the left photon is established the right one h a s its own polarization. It is "an element of reality" in Einstein's term.

From (A) it follows [2] , that the following inequality should hold

$$n(v,\phi_+) + n(\phi_+ ,\Theta_+) \geq n(v,\Theta_+) . \tag{B}$$

Quantum mechanics leads to violation of (B), as it predicts

$$\begin{aligned} n(v,\phi_+) &= \tfrac{1}{2}N\cos^2\phi \quad , \quad n(v,\Theta_+) = \tfrac{1}{2}N\cos^2\Theta \\ n(\phi_+,\Theta_+) &= \tfrac{1}{2}N\sin^2(\Theta-\phi) \quad , \end{aligned} \tag{q}$$

where N is the number of trials, the same for I,II,III series. Hence the following should be satisfied:

$$\cos^2\phi + \sin^2(\Theta - \phi) \geq \cos^2\Theta , \tag{Q}$$

for any ϕ and Θ.This is obviously not true - take for example $\phi=3\Theta$, $0° < \Theta < 30°$.

The experiments confirm (q) i.e. confirm violation of (B) in a way quantum rules predict it.
At the same time an influence, an action at the distance must be rejected because correlation of the outcomes does not depend on the separation distance between left and right polarizers.
Experiments of A.Aspect et all. provide an evidence for that statement.

II. Interpretation.

What is then wrong?
The assumption (A) is wrong. Assumption that the right photon has polarization before it was stated by R. What does this mean: photon has polarization, say " " ? Does it mean that photon has an outcome " " ? An outcome " " is a common result of a device asking questions and a quantum prepared by S.
What photon really is, what photon really has - these are chances, an information, that is to say exactly, it has, it is the STATE |" ">, the state of a whole system.
Note: a source S produces not the outcomes.
It prepares two-quanta states, i.e. it produces chances for outcomes. Which outcomes? All possible. These possibilities are defined by I, II, or III being chosen.
The source S produces two-photon states $|\psi(1,2)>$ which are superposition of two undistinguishable ways to do it: $|h,v>$ and $|v,h>$,where the first label stands for a possible outcome in L, while the other - in R, i.e.

$$|\psi(1,2)> = \tfrac{1}{2}\{|h,v> + |v,h>\} .$$

Put it another words: the first label corresponds to "the left photon", the second one - to the "right one".
What does a detection, say in L, mean?
It destroys, as any detection does, the above superposition of - up to that - undistinguishable ways. It chooses one of then, either $|h,v>$ if "h" is an outcome in L, or $|v,h>$, if "v" is an outcome in L. Therefore, once a state, say $|h,v>$ is detected ("chosen"), we know it certainly. We, or rather LUSUR , knows the state, not the two outcomes, in L and R.
The state $|h,v>$ is chosen. What does this mean?
It means, that the chances of attaining an outcome in R - in any of

those I,II,III - are determined by that state, i.e. by $|v\rangle$ for the R device.
Chances are determined. The outcomes - not.
If the outcomes were certain always (were properties of photons) then (B) should be satisfied.
But we do not have pairs of outcomes while detecting state $|h,v\rangle$ or $|v,h\rangle$, ... , while identifying $|h\rangle$ or $|v\rangle$ in L.

This is perhaps well illustrated by the situation

$$\underset{L}{\boxed{H,V}} \longleftarrow\text{------}\quad S \quad\text{------}\longrightarrow \underset{R}{\boxed{}}\,;\quad \text{L and R space-like separated,}$$

where the type of R is unknown to L. Then L detecting a state does not know the outcome in R.
An information, what was the outcome in R travels to L with a velocity not bigger than the velocity of light. And note: the state $|\psi(1,2)\rangle$ does not "travel" at all. It is. It is defined, it is produced by S. It is property of S. The source S is such that in any situation of LUSUR it determines all chances for all admissible outcomes. The outcomes do not "belong" to S, to state $|\psi(1,2)\rangle$. The out-comes "belong" to LUSUR.
The outcomes are not properties of a quantum. Coming back to assumption (A) we must deny it, i.e. "once polarization state of the left photon is established, the right one does not have its own polarization".

There is then no need for (B) to be satisfied. The superposition principle leads to (q) which contradicts (B). As the identity of a quantum phenomenon is its state, not the outcomes of say localizations in positions or momenta one must recognize, that in general, it has neither of localizations; though chances for this or that one are determined certainly by the very existence of a quantum phenomenon.
We are therefore forced to elaborate a consequent interpretation of canonical commutation relations, misleadingly identified with uncertainty principle, where "uncertainty" term refers to position and momentum of a quantum, while as we have concluded, there do not exist in general such properties of a quantum phenomenon, i.e. there is nothing to be uncertain.
A corresponding proposal is presented in [1] which we now summarize.
As proposed in [1] , the physical meaning of CCR is that it implies total noncommutativity of projection operators from respective spectral families i.e.

$$\left[E(\Delta),\tilde{E}(\tilde{\Delta})\right] |\psi> \neq 0 \qquad \text{(N)}$$

for arbitrary intervals Δ and $\tilde{\Delta}$ of the position and momentum operators spectra, and for arbitrary state. The relation (N) has a transparent meaning.

"Never ($\equiv$ for no state) quantum phenomenon can be assigned by a single act of measurement both localizations".

However, note again that quantum does not have either of localizations. Its actuality is its state i.e. it has definite chances to be localized in any Δ or in separate act, in any $\tilde{\Delta}$, <u>if</u> the appropriate localization $E(\Delta)$ or $\tilde{E}(\tilde{\Delta})$ is being performed by its inevitable macroscopic enviroment.

In particular this means that neither Δ nor $\tilde{\Delta}$ localization is a property - in Piron's sense - of any quantum phenomenon describable by Quantum Mechanics.

REFERENCES

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2 RAE A. "Quantum Physics: illusion or reality?" Cambridge University Press, 1986

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