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Reply to Unruh *

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Abstract

William Unruh has suggested (quant-ph/9710032) that a certain counterfactual statement in my recent nonlocality proof should be re-interpreted in a way that would block the proof. I give reason's why that statement should not be re-interpreted.

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Disclaimer

Unruh[1] emphasizes that, in the use counterfactuals within a quantum context, great care is required to ensure that there is no importation of classical notions of reality.

Great care is certainly required in both directions: we must neither allow improper importations of classical notions of reality, nor blind ourselves to unexpected properties of nature by placing arbitrary constraints on rational analysis.

After all, the basic difficulty that caused the founders of quantum theory to insist that the quantum formalism had to be interpreted as being about "our knowledge", instead of being about physical reality itself—as physical reality had formerly been understood in physics—was the need to reduce wave packets of large extent upon the receipt of new information. This reduction is natural for "our knowledge", but conflicts with locality ideas about physical reality coming from (deterministic relativistic) classical physics.

In view of the controversial nature of this Copenhagen move—of making physics be about human knowledge—it is certainly proper to question whether this peculiar way of evading a nonlocality that is so blatantly present in the mathematical formalism might not be obscuring a nonlocal aspect that is actually present in nature herself. So we must be as much on guard against curtailing rational argumentation as against importing classical ideas about reality: this issue is too important to be settled by classically based prejudices of any kind.

The entire argument is about macroscopic events, such as the setting up of alternative possible experiments, and constraints on the possibilities for outcomes of such experiments. At that level Bohr advocated the use of classical language and logic, and emphasized the freedom of experimenters to examine properties of their own choosing. The entire Bohr-EPR discussion was based on the common agreement that consideration of mutually exclusive alternative possible measurements was not out of bounds.

The step in my proof[2] that Unruh objects to is the step where LOC2 is applied. I had shown that under the condition that L2 is performed a certain statement (S) is true:

(S): If the first measurement was performed in region R and gave the first of the two possible outcomes there then if, instead, the second possible measurement had been performed there then the outcome would have been the first possible outcome of that second measurement.

I take this statement (S) to mean what it says: there is some deep structure in nature that connects what actually occurs under the actually realized experimental conditions to what would have occurred if the quantum/free choice that determined which experiment was performed in region R had gone the other way.

This property was proved, without appeal to determinism or hidden variables, under the condition that L2 was performed (plus the condition LOC1, and the assumed validity of the predictions of quantum theory in this Hardy-type case, and the idea that the choices as to which experiments are performed in the two regions can be treated as independent free variables)

Because experiment L2 is supposed to be performed after everything referred to in (S) has either occurred or not, I claim that if (S) should *fail* to hold under the condition that the later free choice were L1, instead of L2, then there must be some sort of backward-in-time influence: the constraints connecting possibilities of outcomes in region R that is asserted to hold by statement (S) would either hold or not hold according to whether or not the later free choice is to perform L2 or L1. LOC2 is, accordingly, the postulate that (S) *continues* to hold if L1 is performed at the later time, rather than L2. [Since the conjunction of the postulates leads to a contradiction, this postulate is, to be sure, a very likely candidate for rejection.]

Unruh claims that a hidden classical reality assumption is smuggled in here.

I have always stressed in my work on this subject that I am excluding the many-worlds scenarios, in which nature makes no choices: the entire argument is based on the notion of the lack of dependence of nature's choice of which outcome appears upon which free choice is made (later) by a faraway experimenter. This is a reality assumption that I do make.

Most quantum theorist, when not adhering strictly to the Copenhagen position that the theory is about our knowledge, do think in these terms: nature selects the outcomes of the quantum measurements that we choose to perform. This is not a classical idea of reality, because it is about a stochastic selection that has no counterpart in classical mechanics. It is a quantum idea about reality.

Unruh argues that, because a certain outcome of L2 occurs in the *proof* of (S) under condition L2, a failure of property (S) to remain true if L1 is performed, instead of L2, would not constitute a backward in time influence. For him the meaning of (S) is entangled with its proof. I, on the other hand, adhere consistently throughout my proof to the position the (S) is defined as a condition that might or might not be true: it asserts that nature has an aspect that connects what actually happens if one of the experiments is performed in region R to what would have happened there if the quantum event that controls which measurement is performed there had gone the other way. I show that such a constraint can in fact be proved to exist under the condition that L2 is performed.

This interpretation of (S) is its natural meaning: it is what the words say. In any case, it is completely rational for me to consistently interpret (S) this way. For this is the interpretation that, consistently applied, allows us to explore most effectively the character of a possible quantum reality that lies behind the phenomena that is the source of our knowledge of nature.

References

1. W. Unruh, *Is Quantum Mechanics Non-local?* (quant-ph/9710032)

2. H.P. Stapp. *Nonlocal Character of Quantum Theory*, Amer. J. Phys. **65**, 300-304 (1997) (http://www-physics.lbl.gov/ stapp/stappfiles.html)