# Review of: "On the Bell Experiment and Quantum Foundation"

Oskari Kerppo[1]

1 University of Jyväskylä

Potential competing interests: No potential competing interests to declare.

The author gives a fairly detailed description of what he considers pointing to a new foundation for quantum theory. The precise nature of what this foundation is is left pretty vague, unfortunately.

Let me elaborate. The article is about the Bell experiment and the interpretation of its consequences. Namely, in light of Bell's theorem one of two assumptions on Nature must fail: locality or realism, or even both. However, Bell's theorem is not about any specific theory, in particular it's not about quantum theory. Any conceivable theory that we can build cannot be about Nature if it adheres to the principle of local realism.

As I understand, the author does not argue against realism in the sense that there should exist an objective reality that we can attempt to model. Likewise, the author is not against locality. In fact, the author favors locality over realism if anything. In light of Bell's theorem, it is certainly possible to give up realism and stick to locality. Whether or not this is desirable or offers any advantage is left to everyone's own opinion.

Now, coming back to the article, my biggest issue with it is that it is not at all clear to me what it means for an observer to have a variable “in his mind”. I'm a physicist, so if I have a variable in mind, I can at least write a symbol for it on a piece of paper, even if I don't know the precise value. So to me the question really is whether some physical variables exist or have predefined values prior to measurement. Personally I doubt that an observer's mind is in any way relevant to the question. This is my bias, and I admit that my opinion is biased against the results of the article.

I will now give some comments on the manuscript before concluding this review:

---

"In my view, seeking a theory that covers reality in all situations - whatever that means, seems to be impossible. We are not gods. Instead, in my opinion, we should be looking for a theory that is related to our knowledge of reality. Any process of seeking knowledge can be called an epistemic process."

Comment: “I'm not against this in principle. An epistemic interpretation of QM certainly has advantages. The main

question is if such an interpretation can actually work.”

---

“Bell’s inequality has to do with a hypo-thetical reality behind these measurements, and this, in my opinion, is a reality that wedo not seem to be able to cover completely with any human-made model.As I see it,this is in some way all there is to it.”

Comment: “It's a bit more than this. Bell's inequality is about any conceivable theory adhering to local realism. As Nature violates Bell's inequalities demonstrably, the conclusion is that any theory describing Nature cannot be explained by models that are locally real.”

---

Equation 1, a bit of nitpicking on notation:

I understand that the author has a background in statistics. Therefore the typical notation in QM may be confusing. But I have to point out that, as it is written now, the numbers in the ket vectors are not necessary and deviate from normal notation. If the author wants to explicitly point out which ket belongs to which particle, then a subscript would be more suitable.

I'm writing this because the "standard" computational basis for a qubit is usually $|0\rangle$, $|1 \rangle$. Also, $|+\rangle$, $|-\rangle$ is another basis. In normal notation, for instance, $|0\rangle \otimes |+\rangle = |0\rangle |+ \rangle = |0+ \rangle$. So if the numbers 1 and 2 stand for the paritcle identifier, it should be written as $|0\rangle_1 |+\rangle_2$.

---

“In this situation there are physical variables, and the observer will have at least some of these variables, say θ, λ, η,...in his mind.”

Comment: “This is perhaps my biggest issue with the present article. What does it mean that an observer has a variable in his mind? This seems to be poorly defined. As an example, I am a physicist, if I have a variable in my mind, then I can certainly write it on a piece of paper. If I don't know the value of the variable, I can at least give it a symbol, for example . How is it different to have a variable in mind compared to these variables just existing and being knowable/measurable? How is this different from the standard Heisenberg uncertainty principle?”

---

“In the last example, in the spin1/2 case, one can model the discrete spin component in direction a as sign(cos(a,φ)), and letting φ have a uniform distribution on the sphere.”

Comment: “These really sounds like the Kochen-Specker ontological model for the qubit. Notably, the Kochen-Specker model is macimally $\psi$-epistemic, and as such this model is ruled out by the Kochen-Specker Theorem.”

---

“This points at a new foundation of quantum theory, and it also suggests a generalepistemic interpretation of the theory”

Comment: “So far only measurements and measurement outcomes, along with some hypothetical variables that an observer "has in his mind", have been discussed. States have not been discussed. Composite systems have not been discussed. State updates upon measurements, or the "wave function collapse" has not been discussed and finally the Schrödinger equation is not even mentioned. It seems like there is still a long way to go before this approach can be considered a new foundation for QM seriously.”

---

“From this conclusionalso a number of so-called ‘quantum paradoxes’ can be solved”

Comment: “Of course an epistemic approach will apparently solve many paradoxes. Take the Spekken's toy model, for example. It solves the problem of not being able to distinguish quantum pure states perfectly. Unfortunately, this model belongs to a class of ontological models ruled out by the Kochen-Specker Theorem. Just because an epistemic explanation for some puzzling phenomena exists doesn't mean it's a valid explanation. This is my worry in regard the present paper as well. It is so vaguely formulated that it is not easy to say how it relates to the topic of contextuality, for instance. Can this new approach be formulated as an ontological model?”

---

Comment on Theorem 1:

“This really reminds me of incompatibility of observables. Are maximally accessible variables somehow related to incompatibility in QM?”

---

“The inaccessible variables, in this case, are the full spin vector φA of Alice’s particle and the full spin particle φB of Bob’s particle.”

Should be full spin-vector, not particle, for Bob.

Comment: “What is said here is really controversial. Why is it controversial? Given a maximally entangled state it is controversial if there even exists a state for Alice and Bob separately. What exists is the joint state, which is entangled and cannot be expressed as a product state. But here the author assumes there nevertheless exists full spin vectors for Alice

and Bob, and some consequences are derived."

---

"From the discussion above, it seems that it is the assumption of realism which must be abandoned."

Comment: "This is the view of the author. As such I can accept it. However, other views exist. For example, if you read something like (Quantum Measurement, Springer 2016), the authors state in beginning of Chapter 20: "In the case of quantum mechanical violations of Bell inequalities, it is widely understood that the assumption of realism is compatible with quantum mechanics, so that the conclusion is drawn that this theory possesses nonlocal features."."

---

"Every description of reality must be relative to the mind of an
actor (or relative to the joint minds of a communicating group of actors). To be in
agreement with observations, we seem to be forced to the conclusion that the minds of
these actors must be limited in some way in certain contexts."

Comment: "Was physics, or Nature, fundamentally different before any minds existed? What constitutes a mind?"

---

To conclude, I think the article makes some progress towards an epistemic interpretation on quantum mechanics. As such this progress is appreciated. However, as pointed out in the comments, this possible new interpretation is still lacking some key components. More care should be taken to explain how quantum states are related to the accessible variables. Composite systems should be explained along with state update upon measurement and the Schrödinger equation. Only then can the new foundation for quantum theory be revealed for what it should be, according to the author.

I would like the author to answer to the following questions, if possible:

1. What is different in the new approach when comparing to the existing framework of ontological models? At least the spin ½ case is very similar to the Kochen-Specker model.
2. How does the new approach compare to contextuality (Kochen-Specker contextuality or Spekkens' generalized noncontextuality)?
3. Is incompatibiliy relevant in maximal accessible variables?

As I said previously, I'm not convinced that the mind of an observer plays any special role in physics. However, the author has at least in principle the possibility to change my mind. No-go theorems enjoy a special role in foundations of quantum

mechanics. In my mind, the most significant contribution that would be possible in this new approach would be to formulate a novel no-go theorem with clear assumptions. If I, as an observer and physicist, truly cannot have in my mind all relevant variables, then the author should be able to prove it by presenting some scheme for a test that I can implement in my laboratory. But then again, wouldn't this revert to exactly the kind of test that is covered by Bell's theorem? So even if I couldn't have in my mind all variables, I still don't understand how this helps me in understanding Nature.

Regarding publication, I can certainly recommend publication in some format. The article was interesting in my opinion, and makes some progress towards an epistemic interpretation of QM. However, I think presently the article is not really self-contained in the sense that it is not possible to understand the main arguments in full detail without looking up the additional references. These additional technical details would be appreciated, especially as it is not clear to me that the peer-review status of the other publications are.