Review of: "Further comments on ‘Is the moon there if nobody looks? Bell inequalities and physical reality’"

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The experimentally confirmed violation of the CHSH-Bell inequality lies at the core of a heated discussion about the foundations of quantum mechanics, and physics in general. The violation of the inequality is in agreement with the predictions of quantum mechanics. However, according to Bell's theorem, any theoretical framework that shares certain physically intuitive features must be constrained by the inequality and, therefore, cannot reproduce these predictions or the experimental results.

Around this issue, two vehemently opposed groups have emerged. On one side, the "believers" are firmly dedicated to consecrating the idea that the observed violation of Bell's inequality implies that some of the most fundamental physical notions, usually taken for granted in our descriptions of the macroscopic world, must be abandoned. On the other hand, the "non-believers" oppose this drastic conclusion, but they do not really know why.

Over the last fifteen years, R. Gill has become the spearhead of the "believers" crusade to beat, one by one, all the attempts of the "non-believers" to raise their voices. In this paper, he picks on M. Kupczynski's latest work.

Even though I think that R. Gill and his fellow "believers" are missing a crucial aspect of the physics involved in Bell's experiments and, hence, I disagree with the conclusions that they reach from the observed violation of the Bell inequality, I must admit that I agree with the criticisms that he raises about M. Kupczynski's latest papers. In this review, I focus on M. Kupczynski's latest model, as R. Gill does in his paper.

M.Kupczynski claims to have a "contextual model" of local hidden variables capable of reproducing the predictions for quantum mechanics for the CHSH-Bell experiment and, in general, any other set of possible correlations. I will briefly outline here the master lines of his proposed model. As we will see, his model allows anything (and, in particular, it allows signaling) without any guiding physics at all and, hence, nothing can be learnt from it

The Bell experiment involves two parties, A and B, who share pairs of entangled qubits. Each party is equipped with a detector that can be freely oriented within its locally defined XY plane. Let shall denote the orientation of detector A with respect to its local lab frame as **a**, and the orientation of detector B as **b**.

Each detector measures the polarization of its incoming qubit, and produces a binary outcome, denoted generically as $x, y \in \{-1, +1\}$ for detectors A and B, respectively.
Quantum mechanics predicts that for any given setting of the two detectors, the probabilities for each one of the four

possible outcomes of the experiment are given by

$$\tilde{p}_{\mathbf{ab}}(x = +1, y = +1) = \tilde{p}_{\mathbf{ab}}(x = -1, y = -1) = (1 - \mathbf{a} \cdot \mathbf{b})/4 \tilde{p}_{\mathbf{ab}}(x = +1, y = -1) = \tilde{p}_{\mathbf{ab}}(x = -1, y = +1) = (1 + \mathbf{a} \cdot \mathbf{b})/4$$

Now, let's build a trivial "contextual model" that reproduces these predictions: let$(\lambda_a, \lambda_b) \in \{-1, +1\}$ be two binary input variables occurring with the same probabilities defined above for the variables x, y:

$$p_{\mathbf{ab}}(\lambda_a = +1, \lambda_b = +1) = p_{\mathbf{ab}}(\lambda_a = -1, \lambda_b = -1) = (1 - \mathbf{a} \cdot \mathbf{b})/4 p_{\mathbf{ab}}(\lambda_a = +1, \lambda_b = -1) = p_{\mathbf{ab}}(\lambda_a = -1, \lambda_b = +1) = (1 + \mathbf{a} \cdot \mathbf{b})/4$$

and let also define "contextual" response functions for each one of the detectors such that

$$x = f_{\mathbf{a}}(\lambda_a) = \lambda_a, \qquad y = f_{\mathbf{b}}(\lambda_b) = \lambda_b,$$

Two conclusions are trivially obvious about this model: 1) This model trivially "reproduces" the predictions of quantum mechanics reported above; 2) This model does not teach us anything.

This trivial construction is the basic skeleton of M.Kupczynski's model. In order to hide it, M.Kupczynski allows his model to depend on additional variables (λ_1, λ_2) supposedly carried by the pair of entangled qubits, and he also extends the domain of the variables (λ_a, λ_b), but the actual capability to "reproduce" the predictions of quantum mechanics (or whatever other set of probabilities that you want) can be traced back to the described trivial skeleton.