Reply to Comment on "Surrealistic Bohm Trajectories"

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Let us begin with a response to the summary of the Comment by D. Dürr, W. Fusseder, S. Goldstein, and N. Zanghi [1]. We are accused to not stay inside "orthodox quantum theory" but to employ a "naive, largely incoherent operationalism" instead. We think that this charge is not justified, because we did apply standard quantum theory correctly and also followed the rules of Bohmian Mechanics (BM) carefully. In the following we react to the more essential points of the Comment in some detail.

The Comment suggests that we have conceded "many virtues" to BM and that we have admitted that standard quantum theory is "plagued by notorious conceptual difficulties". This is not the case. On the contrary, we maintain that BM is not needed to have the Schrödinger equation "embedded into a physical theory". Standard quantum theory has already clarified the significance of Schrödinger's wave function as a tool used by theoreticians to arrive at probabalistic predictions. It is quite unnecessary, and indeed dangerous, to attribute any additional "real" meaning to the ψ-function.

The semantic difference between "inconsistent" and "surrealistic" is not the issue. It is the purpose of our paper to show clearly that the interpretation of the Bohm trajectory – as the real retrodicted history of the atom observed on the screen – is implausible, because this trajectory can be macroscopically at variance with the detected, actual way through the interferometer. And yes, we do have a framework to talk about path detection; it is based upon the local interaction of the atom with the photons inside a resonator, described by standard quantum theory with its short range interactions only.

Perhaps it is true that it is "generally conceded that ... [a measurement] ... requires a ... device which is more or less macroscopic," but our paper disproves this notion, because it clearly shows that one degree of freedom per detector is quite sufficient. That is the progress represented by the quantumoptical which-way detectors. And certainly, it is irrelevant for all practical purposes whether "somebody looks" or not; what matters only is that the which-way information is stored somewhere so that the path through the interferometer can be known, in principle.

The authors of the Comment seem to have missed an essential point. It is not important that one *first* detects the atom on the screen (at $t = 5\,T_0$) and *then* reads off the one-bit detectors. Nothing changes if the detectors are read off at $t = 4\,T_0$, say, because then the atom is already beyond the cross-over region, and the change in the Bohm velocity field resulting from the state reduction is irrelevant as far as our conclusions are concerned.

Nowhere did we claim that BM makes predictions that differ from those of standard quantum mechanics. The whole point of the experimentum crucis is to demonstrate that one cannot attribute reality to the Bohm trajectories, where reality is meant in the phenomenological sense. One must not forget that physics is an experimental science dealing with phenomena. If the trajectories of BM have no relation to the phenomena, in particular to the detected path of the particle, then their reality remains metaphysical, just like the reality of the ether of Maxwellian electrodynamics. Of course, the "very existence" of the Bohm trajectory is a mathematical statement to which nobody objects.

We do not deny the possibility that some imaginary parameters possess a "hidden reality" endowed with the assumed power of exerting "gespenstische Fernwirkungen" (Einstein). But a physical theory should carefully avoid such concepts of no phenomenological consequence.

Funding agencies were and are well advised to support experiments that have probed or would probe the "surprises" of quantum theory. Imagine the (farfetched) situation that the experimenter finds the photon always in the resonator through which the Bohm

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trajectory passes rather than in the one predicted by quantum theory. Wouldn't that please the advocates of BM?

Let us close with a quote from the writings of Y. Aharanov [2]: "Bohm's pathbreaking hidden variable theory of 1952 is often accused of artificiality and inelegance, and doubtless it is guilty of both." Irrespective of what can be said in addition, we think that we have done a useful job in demonstrating just how artificial the Bohm trajectories can be.

[1] D. Dürr, W. Fusseder, S. Goldstein, and N. Zanghi, Z. Naturforsch. **48a,** 1261 (1993).
[2] Y. Aharanov and D. Albert, The issue of retrodiction in Bohm's theory in: Quantum Implications, edited by B. J. Hiley and F. D. Peat (Routledge and Kegan Paul, London 1987).