The philosophical relevance of Bohm's interpretation of quantum theory

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Structure of talk

- Part 1: General remarks on Bohm
- Part 2: Comments on the philosophical relevance of the deBroglie-Bohm theory

Part 1: General remarks on Bohm

Background

- I first met Bohm in a philosophical context in 1980 (implicate order, meaning, dialogue…)
- became later interested in the causal interpretation
- joint work with Bohm (1987-1992) on applying the causal interpretation to philosophy of mind / cognitive science; left unfinished
- PhD 1992 ”Mind, matter and the implicate order. The relevance of David Bohm’s interpretation of quantum theory to cognitive science”

- subsequently worked with Basil Hiley
- Hiley, B.J. and Pylkkänen, P. (2005), “Can mind affect matter via active information?”, *Mind and Matter,* vol. 3, no. 2, pp 7-26.
- http://www.mindmatter.de/mmpdf/hileywww.pdf

Personal reminiscences

- [freely described in the audiotape]

How many Bohms?

- Valentini: 3
  - The Copenhagen/complementarity/Bohr Bohm
  - The deBroglieBohm
  - The ”Eastern” Bohm

- It is true that Bohm had a close interaction with Krishnamurti
- However: this was only one influence upon him after the 1960s
- The ”third” Bohm is much broader and deeper, both scientifically and philosophically than ”New Age thinking”
- The relevance of Bohm’s work after the early 1960s remains to be evaluated!

d’ Espagnat on Bohm

- ”[foundations of physics] essentially consists in trying to bring some more light into the implicit views, assumptions, concepts and the like that tacitly underlie our thinking”
- Einstein: what is most basic in physics is not the mathematics but rather the set of the underlying concepts

d’ Espagnat cont.

- ”It is of course clear that David Bohm ranks first among the physicists of our generation who illustrated through their example the deep truth of Einstein’s maxim”

d’ Espagnat cont.

- ”Many of us – including the present writer – were awakened from a kind of ’dogmatic slumber’ (to take up Kant’s words) by reading his 1952 papers”

d’ Espagnat cont.

- ”But most certainly (as his later work shows) Bohm would, more emphatically than anyone else, advise us not to just jump from one dogma to another.”

- d’Espagnat (1987), ”Meaning and being in contemporary physics”, in Hiley & Peat (eds) *Quantum implications.* London: Routledge.

Paavo's comment on d'Espagnat

- Unlike many others, d'Espagnat sees in positive light Bohm's continual attempts to understand the quantum theory from different points of view

Why did Bohm ”give up” his causal interpretation?

- ”Because the response to [the causal interpretation] was so limited, and because I did not see clearly, at the time, how to proceed further, my interests began to turn in other directions”
- Bohm’s short scientific autobiography ”Hidden variables and the implicate order”, published in Hiley & Peat (eds) *Quantum implications.*

What were the ”new directions”?

Order

- ”During the 1960s I began to direct my attention toward *order*, partly as a result of a long [over 4000 page!] correspondence with an American artist, Charles Biederman, who was deeply concerned with this question.”

- Bohm, D. and Biederman, C. (1999*) The Bohm-Biederman Correspondenee. Volume one: Creativity and Science*. London: Routledge. Ed. P. Pylkkänen.

Language

- ”…through working with a student, Donald Schumacher, I became strongly interested in language.”
  - Bohm admits somewhere that he felt he understood Bohr properly only after discussions with Schumacher
  - So the 1951 Bohm might not be a true ”Bohrian” Bohm
  - Even ”Bohrians” (like Plotnitsky) agree that the later Bohm truly understands Bohr

Bohm to Wilkins (1987, tapes 9-16, p. 94)

- ”During this period [PP: 1960s??] which I found somewhat depressing as far as physics was concerned, we got a student, Donald Schumacher, [who] was quite brilliant. He came from America … . He took a great interest in Niels Bohr. He really studied Niels Bohr and he had some insights into Niels Bohr. Bohr is exceptionally hard to understand. I wrote a book *Quantum Theory [1951]* which I thought was on Bohr’s philosophy, but it probably was not. It was a bit closer to Pauli’s philosophy. Pauli was regarded as one of the architects of the Copenhagen Interpretation, and yet you can see big differences between him and Bohr. I had come out with something which Pauli liked a great deal and Bohr never commented on.”

The David Bohm Papers, Birkbeck Library, University of London

WILKINS: You mean when you sent it to them?

BOHM: Yes. I can see know that Bohr could not have said anything to me, because it would have been very embarrassing to him to say that I praise Bohr so highly, and he would have to say that I had it all wrong. But Pauli liked it, because my ideas are really much closer to Pauli than to Bohr.

The point is, I had not really understood Bohr, but I had sort of seen him the way I wanted to see him. Because he was so hard to understand, I sort of began to read my own view in there. This fellow Schumacher had some insight which made it much more clear what Bohr was about.

What he said could be summed up by saying that the form of the experimental conditions and the meaning or content of the results are a whole, not further analyzable."

Bohm's autobiographical discussions with (Nobel laureate) Maurice Wilkins,The David Bohm Papers, Birkbeck Library, University of London

Toward the implicate order…

- These two interests (order, language) led to a paper on order in physics and on its description through language
- DB compared and contrasted relativistic and quantum notions of order, leading to the conclusion that
  - they contradicted each other and that
  - new notions of order were needed.

-> Implicate vs.explicate order

Part 2: Comments on the philosophical relevance of the deBroglie-Bohm theory

[Focus on Bohm's 1952 papers & subsequent development rather than deBroglie]

”Obviously” relevant to these philosophical issues

- Determinism vs. indeterminism
- Realism vs. instrumentalism

Might be relevant to these

- The mind-body problem (the problem of mental causation, the problem of consciousness…)
- The problem of naturalizing intentionality/ meaning
- Dispositions
- Modalities

Arthur Fine 1996

”On the interpretation of Bohmian mechanics”

- Theme: ”interpretive latitude contributes to heuristic power.”
- Note by Paavo P.: what follows next is a short tutorial on parts of Fine’s article, with some comments. I felt it would be important for the conference to be aware of some of the best philosophical discussion of the Bohm theory. Also, I have added to these slides some critical comments that I did not present in the conference.

Summary of interpretive options for Bohmian Mechanics (= BM) according to Fine

- Dualism vs. Monism
- Determinism vs. Indeterminism
- Quasi-realism vs. Fictionalism about momentum & the trajectories
- Realism vs. Instrumentalism about the wave function
- With vs. without quantum potentials and forces

Wave-particle duality?

- Fine: Where QM merely flirts with dualism but avoids commitment, BM embraces it
- BM requires both wave (= Ψ function) and particle (= position coordinates) in order to specify the state of the system.
- Einstein (1931): such dualism must be disturbing to every orderly mind

Fine cont.

- But: is the dualism of BM really of a sort to disturb an orderly mind?
- For: the wave is defined on configuration space
  - > it is essentially dependent on all the possible particle positions
- Measuring particle positions actually determines it

Fine cont.

- But: the particles are informed and guided by the wave which makes their possible positions likewise dependent on the wave
- The line of actual influence is one way, since the wave affects the actual motion of the particles, and not conversely

Radical holism a la Fine

- This interdependence suggests that we might think more holistically not of two distinct kind of entities, but of one new kind
- If we think globally then we have a single entity everywhere at once whose nature makes ”what each thing *is*” depend on ”all other things, with which it is thus indivisibly related”.

Fine cont.

- Thus it is a Bohmian X without separable parts
- It changes over time but it does not move since, being everywhere at all times, it has no place to move to
- Certainly this is a new synthetic conception and, despite its obvious tensions with relativistic spacetime, not something for which ”dualism” seems an appropriate label

Cf. Bohm 1957, p.117

- ”…our model in which wave and particle are regarded as basically different entities, which interact in a way that is not essential to their modes of being, does not seem very plausible. The fact that wave and particle are never found separately suggests instead that they are both different aspects of some fundamentally new kind of entity which is likely to be different from a simple wave or a simple particle, but which leads to these two limiting manifestations as approximations that are valid under appropriate conditions”

Bohm, D. (1957/1984) Causality and Chance in Modern Physics. London: Routledge.

Hiley 2010

- ..we [DB & BJH] concluded … that this [quantum] potential enabled the global properties of quantum phenomena to be focussed on the particle aspect, but in doing this we must remember the `particle' is not independent of the background.
- Furthermore it is the quantum potential that contains the effect of this background.
- This implies that the particle and quantum potential form an indivisible whole, which for the sake of simplicity, we can call a `quantum blob'

Hiley, B.J. (2010, preprint) "Some Remarks on the Evolution of Bohm's Proposals for an Alternative to Standard Quantum Mechanics."

Determinism

- Dürr, Goldstein and Zanghi: ”Bohmian mechanics is clearly a deterministic theory…” (1996: 23)
- Fine: that is the conventional view of BM, but not the only possible

Fine: there's another possibility…

- Go back to the Laplacian idea that determinism is about seeking the **possibility of accurate prediction**

Fine cont.

- We can regard determinism (or causality) as standing or falling with the possibility of exact prediction
- Schlick, Carnap (the Vienna Circle, logical positivism)

Fine cont.

- BM is deterministic in principle
- But: for all practical purposes we find
  - the **same limitations on predictability** there as in QM, and hence
  - the **same degree of indeterminism**

Fine cont.

- Since determinism no longer functions to insure ever higher degrees of predictability, is this
  - a **distinction without a difference**?

Fine's 2 options

- Determinism understood ontically: BM is a theory of a deterministic world that, ironically, we may only grasp as though it were indeterministic
- Determinism understood epistemically: BM urges us to abandon determinism as it shows that it is fruitless to seek after exact predictability

Paavo's comment on 1st option

- Consider determinism understood ontically (i.e. BM is a theory of a deterministic world that we may only grasp as though it were indeterministic)
  - note that Bohm and Vigier proposed already in 1953 a stochastic version of the theory.
  - Bohm himself was not committed to the idea of a deterministic world!
  - if the "quantum world" has a stochastic aspect, this explains why we may (currently) only grasp the world as though it were indeterministic (= no irony(?))

Paavo's comment on 2nd option:

- Consider determinism understood epistemically (i.e. BM urges us to abandon determinism as it shows that it is fruitless to seek after exact predictability)
  - note that the tone of Bohm's 1952 papers is such that it is fruitful to seek after more exact predictability!
  - e.g. "…with the aid of such modifications in the theory, we could in principle measure the particle positions and momenta precisely, and thus violate the uncertainty principle", p. 171 (-> paper II, section 6)

Paavo's comment on 2nd option cont.

- So: BM shows that it is fruitless to seek after exact predictability only if we assume that BM is a final theory
- This was not at all Bohm's tone in the 1952 papers, nor subsequently

Realism

Fine's specific two-part criterion of reality

- **Observer-independence:** if something is real then it exists whether or not it is observed
- **Accessibility:** measurement reveals its pre-existing situation

Fine urges this not as a sufficient but as a necessary condition for judging that something is real

Paavo's comment

- Let's consider the criterion of accessibility, i.e. that measurement should reveal its pre-existing situation
- A typical realist might consider it reasonable to assume that a certain pre-existing situation is real even if measurement cannot reveal it

Paavo's comment cont.

- The whole point of realism is to allow for assumptions (or hypothesies) about unobservables, if there are good reasons to make such assumptions
- It seems that Fine applies a strong empiricist criteria, and this way manages to rob many aspects of BM their reality

Paavo's comment cont.

- A Bohmian realist might respond that s/he does not believe that the unobservable things exist, while adding that it is a reasonable hypothesis that they do.

Fine cont.

- It seems reasonable to ask how seriously the particle trajectories themselves ought to be taken
- Do the particles really move, or do the calculated trajectories function as intervening variables that could be eliminated?
  - Bohm(PP): the trajectories should be taken as a hypothesis about what may be going on!

Fine cont.

- Might the principle of Occam's Razor urge us to pare away everything from BM that is not simply QM?
  - Paavo P.: if you are a strict empiricist, then surely you are likely to pare away everything you cannot observe
- Even Fine: perhaps we should not pare away quite everything!

Fine cont.

- The continuous trajectories provided by the velocity field might be eliminated as ”real“
- But: if the association of position coordinates with the wave function also goes we are left with the **problem of actuality**

- Fine: both Bohr's and Heisenberg's view makes a mystery of
  - how any object ever comes to possess any property; that is, of
  - how **anything at all actually happens**

Fine cont.

- What emerges is a random variables representation of the position variable involving particles that are ***as if*** they move according to the velocity field
  - on this interpretation what is real is the wave function and that there are determinate particle positions and nothing else

Fine cont.

- At the heart of BM is the wave function and determinate particle positions, and perhaps we need be realist about nothing else.

Fine cont.

- In this interpretation the wave function does not actually guide the moving particles.
- It just assigns particle positions and shifting distributions
- Thus one might regard Ψ as a kind of global hidden hand with just these functions

Fine cont.

- The instrumentalist option: Ψ is simply a tool for how we are to take account of the environment in setting up a model of an experimental situation

- The monistic picture: reality consists of a unitary global X that organizes particle aspects everywhere and at every moment in accord with a changing wave aspect

With or without quantum potentials?

- Durr, Goldstein, Zanghi (DGZ): ”Bohm’s rewriting of Schrödinger’s equation via variables that seem interpretable in classical terms does not come without a cost.”
- Paavo P (PP): but how do you interpret in classical terms

$Q = -h^2/2m\ (Grad)^2 R/R$

Isn’t Q highly non-classical?

- DGZ: ”The most obvious cost is increased complexity: Schrödinger’s equation is rather simple, not to mention linear, whereas the modified Hamilton-Jacobi equation is somewhat complicated, and highly nonlinear – and still requires the continuity equation for its closure”
- PP: who knows which gives a better description what is actually ”out there”?

- DGZ: ”The quantum potential itself is neither simple nor natural”
- PP: nature at the quantum level may not be simple and (what our intuitions call) ”natural”

- DGZ: ”It might also be objected that notions such as … the quantum potential are necessary if BM is to provide us with any sort of *intuitive* explanation of quantum phenomena, i.e. explanation in familiar terms, presumably such as those involving only the concepts of classical mechanics.”
- PP: Bohm’s later interpretation of the quantum potential as active information can hardly be seen as relying on ”classical mechanics”.

- DGZ: ”…in the present century fundamental physics has moved sharply away from the search for … intuitive explanations in favor of explanations having an air of mathematical simplicity and naturalness, if not inevitability, and this has led to an astonishing amount of progress”
- PP: again, who knows what sort of explanations best describe what is actually ”out there”. Nature might not (always) care about mathematical simplicity and naturalness.

Summary of interpretive options for BM according to Fine

- BM is a dualistic theory (wave + particle) that could also be monistic (an undivided X)
- The evolution equations of BM certainly make it deterministic
  - except in so far as determinism really has to do with predictability, in which case it is indeterministic

Fine's summary cont.

- Momentum (and perhaps other dynamical variables of "realist" BM) depart from the realist ideal of an accessible, observer independent realm
  - these variables are at best quasi-real or, more radically, fictional
  - the particle motions, the Bohmian trajectories in configuration space, are subject to similar interpretations

PP note on the previous slide

- Is accessibility really part of the ”realist ideal”?
- Isn’t the whole point of realism to take seriously even those aspects which are not accessible, if there are good reasons to do this?

Fine's summary cont.

- This leaves the wave function which could be read as
  - a holistic hidden hand, or
  - as an instrumental Bornian probability guide
- BM can be done with quantum potentials and forces, or without

Fine's summary cont.

- There seem to be choices sufficient for different philosophical creeds and ideologies
  - we know from the Newtonian case that interpretive latitude contributes to heuristic power
  - BM emerges as a real theory with good prospects

Paavo's summary

- Fine advocates a pluralistic approach to interpreting "Bohmian mechanics"
- This is positive
- Perhaps one day people are ready to consider seriously Bohm and Hiley's truly radical ideas such as
  - the interpretation of the quantum potential as active information, or
  - the more general implicate order scheme

Literature

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