

*Unfolding the Big Picture*  
*Essays in Honour of Paavo Pylkkänen*

Edited by Petteri Limnell and Tere Vadén

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# Bohmian Holism

Tuomas E. Tahko

## *1. Introduction*

Anyone who has spent some time chatting about philosophy (or other things) with Paavo will have heard about his appreciation of and friendship with David Bohm. Bohm's influence on Paavo's work is clear, but it goes beyond a mere replication of Bohm's ideas on one hand or a simple source of inspiration on the other hand. I take it that Paavo has always been interested in Bohm as a system *builder*. In this regard, his enthusiasm with Bohm reminds me of my own relationship with E.J. Lowe's (e.g., Lowe 2006) work—and indeed Bohm and Lowe do share a similar type of passion for an overall world view. A key part of such a project is to determine what is *fundamental* (cf. Tahko 2018). For Lowe, there are four fundamental categories of reality, including individual substances (objects). For Bohm, things are perhaps somewhat less clear, probably because, being a physicist, Bohm was acutely aware of the complications that quantum theory introduces when it comes to the question of individuality, and hence the existence of traditional categories like that of individual substances. It is this aspect of Bohm's work, and by proxy, Paavo's work, that I would like to focus on. I suspect that without Paavo's vehement promotion of philosophy of physics during our time as colleagues at Helsinki,

I would not have the capacity to understand even half of the literature in philosophy of physics that I now understand (and I don't understand half of it!). Now, being James Ladyman's colleague, I find the limited knowledge of philosophy of physics that Paavo inspired me to gather to be an invaluable resource. Indeed, the metaphysics of physics is now one of my core areas of interest. So, it is with pleasure that I will go on to discuss one particularly interesting aspect of this area.

I will take my cue from a recent paper, co-authored by Pylkkänen, Hiley, and Pättiniemi (2015). This paper focuses on Bohm's views about individuality and the possible reconciliation of individuality with the *holistic* aspects of quantum theory. These aspects have led some, like Ladyman and Ross (2007), to argue that there are no individuals, just relations—this is the upshot of their *ontic structural realism* (OSR). Taking this thought further, some authors (Ismael and Schaffer, forthcoming) have taken the holistic approach to its extreme and argued that the cosmos as a whole is the most fundamental thing (since it forms one vast entangled system); this is a form of *priority monism*. Pylkkänen, Hiley, and Pättiniemi examine where Bohm's view might fall among these options. The result is interesting: there is clearly an element of holism involved—let us call it *Bohmian holism*—but it does not appear to be of the eliminative type that some versions of OSR might promote, nor the priority monist's version of quantum holism.

## 2. *The Holistic Features of Bohm's Theory*

Since I am hardly an expert on Bohm myself, I will largely rely on Paavo's work to report the holistic aspects of Bohm's theory. Any physicist working on quantum theory will have to learn to live with the strange phenomenon of entangled systems and the resulting seeming lack of individuality. Bohm was no exception, and in his earlier work this can be seen clearly. Here is a

passage from his 1951 textbook, cited also by Pylkkänen, Hiley, and Pättiniemi:

Quantum theory requires us to give up the idea that the electron, or any other object has, by itself, any intrinsic properties at all. Instead, each object should be regarded as something containing only incompletely defined potentialities that are developed when the object interacts with an appropriate system. (Bohm 1951: 139.)

At first look, this is indeed a radically anti-individualist passage, as the outright denial of intrinsic properties goes squarely against any individualistic intuitions. However, there is a way to read this passage which is not perhaps quite so radically anti-individualistic, as Bohm does leave room for *potentialities*, and it might be possible to interpret such potentialities, incompletely defined as they may be, as *dispositional properties* (cf. the line developed in Conroy, O'Conaill, and Tahko ms.). In any case, it seems that Bohm (1987) later changed his views on the matter, motivated, as Pylkkänen, Hiley, and Pättiniemi put it, by dissatisfaction with the fact that the usual interpretation of quantum theory did not provide an ontology, i.e., a comprehensive and systematic view of quantum reality that would go beyond the experimental phenomena. This is precisely why I regard Bohm as a system builder: he seems to have wanted to develop a unified picture of reality. Indeed, as we know from Paavo's work (e.g., Pylkkänen 2007), this attempt to unify different aspects of reality went much further than philosophy of physics.

So, where does the ontology come from? For Bohm, it apparently comes from Schrödinger's equation, giving rise to what was first called the 'causal interpretation' and later Bohm and Hiley's 'ontological interpretation' of quantum mechanics. One crucial aspect of this interpretation is that where the standard Copenhagen interpretation does not postulate any real

existence to quantum particles prior to observation, nor to the wave described by the wave function, Bohm's causal interpretation postulates an objective existence to both. Here is an interesting passage extracted from his book *Science, Order, and Creativity*:

Although the interpretation is termed causal, this should not be taken as implying a form of complete determinism. Indeed it will be shown that this interpretation opens the door for the creative operation of underlying, and yet subtler, levels of reality. The theory begins, in its initial form, by supposing the electron, or any other elementary particle, to be a certain kind of particle which follows a causally determined trajectory. (In the later, second quantized form of the theory, this direct particle picture is abandoned.) Unlike the familiar particles of Newtonian physics, the electron is never separated from a certain quantum field which fundamentally affects it, and exhibits certain novel features. This quantum field satisfies Schrödinger's equation, just as the electromagnetic field satisfies Maxwell's equation. It, too, is therefore causally determined. (Extract from Bohm in Nichol 2005: 185).

Now, this might be a good place to note that the contemporary theory known as 'Bohmian mechanics' and the 'primitive ontology' approach differ in some important ways from Bohm and Hiley's later quantum potential developments. According to Bohmian mechanics: 'we get a deterministic particle mechanics directly from the first-order guidance equation involving the velocities of the particles' (Pylkkänen, Hiley, and Pättiniemi 2015: 231; see also Goldstein 2017). But what I find interesting in the above passage from Bohm is the clear commitment to the reality of the 'quantum field' that satisfies Schrödinger's equation. This idea can be fruitfully compared with *wave function realism*, i.e., the view that 'the wave function is a

fundamental object and a real, physical field on configuration space' (Ney 2013: 37; for further discussion, see Tahko 2017). Ismael and Schaffer have developed full-blown quantum holism based on this idea. Here is their very simple example:

[Q]uantum mechanics seems to allow two entities—call them Alice and Bob—to be in separate places, while being in states that cannot be fully specified without reference to each other. Alice herself thus seems incomplete (and likewise Bob), not an independent building block of reality, but perhaps at best a fragment of the more complete composite Alice-Bob system (and ultimately a fragment of the whole interconnected universe). (Ismael and Schaffer 2020: 4132)

But the quantum holist faces a problem: in what sense, besides in *appearance only*, are Alice and Bob individual and distinct at all, if they are fundamentally nonseparable? Ismael and Schaffer entertain various ways in which we might consider Alice and Bob to emerge as 'modally connected non-identical events' from a common portion of reality (ibid., 4146). It is the option based on wave function realism that interests me here, as it may help us better understand what type of holism Bohm's theory might entail. Ismael and Schaffer suggest that: 'For the wave function realist, assuming that there is even such a thing as familiar three-dimensional space, it is to be treated as a *derivative* (or *emergent*) structure, and not a fundamental aspect of reality' (Ismael and Schaffer 2020: 4152).

Returning to Bohm's (and Hiley's) project, we may now introduce the notion of an 'undivided universe', which 'requires not only a listing of all its constituent particles and their positions, but also of a field associated with the wave-function that guides their trajectories' (Healey 2016: §9; see, also Bohm and Hiley 1993). This is the idea of a 'pilot-wave' postulated in the de Broglie–Bohm theory, which also connects with the

phenomenon of *decoherence*. Decoherence concerns the appearance of classicality when quantum coherence is removed.<sup>1</sup> To briefly outline this idea, we can take the double-slit experiment as our starting point. To get the correct result for the probability of an electron passing through a particular slit, we have to take into account *interference*, which depends on both components of the wave that splits when it encounters the slits. This produces the familiar interference pattern. Now, decoherence becomes evident when this trademark feature of quantum systems, the interference, is not observed and instead we have a system that appears to conform to a classical interpretation. But the reason for this appearance of classicality is that a system will also interact with its environment and indeed it will become entangled with its environment. This phenomenon can be produced simply by performing the double-slit experiment and observing the slits. So decoherence gives us the appearance of wave function collapse without requiring that such a collapse really occurs. But decoherence can also emerge spontaneously, because the system unavoidably interacts with stray air particles etc. From this upshot, it is not a long way to the idea of a universal wave function and indeed quantum holism.

In the de Broglie-Bohm theory, as Bacciagaluppi notes, there are some further issues, as we effectively have two mechanisms connected to apparent collapse and hence the emergence of classicality (Bacciagaluppi 2016: §3.2.1.). So, the Bohmian project, just like Ismael and Schaffer's quantum holism, will have to answer the question of where the

1. For an in-depth introduction to decoherence, see Bacciagaluppi (2016). For an accessible account of the philosophical implications of decoherence, see Crull (2013). See also Wallace (2012) for an extensive discussion of decoherence and the emergence of 'macro-objects'. As Crull (2013: 879) notes sometimes 'classicality' is just understood as 'lack of interference'.

classicality emerges *from*, but the reason why it might appear attractive is that the de Broglie-Bohm theory can refer to decoherence when it comes to the emergence of classical structures and also provide an interpretation of quantum mechanics that ‘explains why these structures are indeed observationally relevant’ (Bacciagaluppi 2016: §3.2.1.). Yet, despite all this, Pylkkänen, Hiley, and Pättiniemi argue that individuality is preserved in Bohm’s theory, and indeed we saw in the earlier quote from Bohm that it seems to be in the spirit of Bohm’s causal interpretation to have *both* individuals and the holistic aspect introduced by the objective take on the quantum field represented by Schrödinger’s equation. But how can we reconcile individuals with these holistic aspects?

### 3. *Whither Individuals?*

What is the nature of individuality in the Bohm theory? Pylkkänen, Hiley, and Pättiniemi present a highly interesting discussion of this, contrasting their proposal with the critical remarks that Ladyman and Ross make about the Bohm theory. Pylkkänen, Hiley, and Pättiniemi cite one of the few passages from Ladyman and Ross where they consider the Bohm theory; I’d like to draw attention to just a small part of this passage: ‘The dynamics of the theory are such that the properties, like mass, charge, and so on, normally associated with particles are in fact inherent in the quantum field and not in the particles. It seems that the particles only have position’ (Ladyman et al. 2007: 136n). The upshot would then be that in order to maintain any semblance of individuality here, something like *haecceities* need to be appealed to, given that the properties associated with the particle are only ‘aspects’ of the quantum field. Ladyman and Ross appeal to Harvey Brown et al. (1996) here, but Pylkkänen, Hiley, and Pättiniemi protest that in fact Brown et al. do not suggest that the properties of particles would only be inherent in the quantum field and not in the particles

themselves. Instead, the thought is that certain experiments suggest that the properties could not only be associated with the particle (i.e., the quantum field needs to be taken into account as well). So, the solution that Pylkkänen, Hiley, and Pättiniemi (2015: 234) suggest is that properties like mass, charge, and so on reside both in the particle aspect and in the field aspect of the individual system.

I believe that the suggested solution is plausible, but it leaves a number of questions open. Specifically, what is the relationship between these two aspects—the particle aspect and the field aspect? There are hints of a number of possible solutions in Pylkkänen, Hiley, and Pättiniemi. But one challenge here is that Bohm himself did not really put forward a fully developed ontology: the ontological status of individual particles in Bohm's theory can be interpreted in at least two different ways. Now the literature is largely dominated by just one view, which we already mentioned in passing, namely Bohmian mechanics and primitive ontology. As Pylkkänen, Hiley, and Pättiniemi report, at least on some versions of this view (e.g., Goldstein and Zanghi 2013), the wave function has merely a *nomological*, law-like role rather than a concrete, objective existence. Yet, this would seem to go against Bohm's original idea, as we saw in the last section—Bohm suggested that the quantum field satisfies Schrödinger's equation, just as the electromagnetic field satisfies Maxwell's equation. Accordingly, Pylkkänen, Hiley, and Pättiniemi are quite justified in suggesting an alternative interpretation, and I think that the core of that interpretation is the following point: 'in the Bohm theory there can be a nonlocal connection between particles that depends on the quantum state of the whole, in a way that cannot be expressed in terms of the relationships of the particles alone' (Pylkkänen, Hiley, and Pättiniemi 2015: 243). Let me also cite the passage from Bohm and Hiley that they appeal to:

Something with this sort of independent dynamical significance that refers to the whole system and that is not reducible to a property of the parts and their inter-relationships is thus playing a key role in the theory. ... *this is the most fundamental new ontological feature implied by quantum theory.* (Bohm and Hiley 1987: 332.)

The holistic aspect of this line of thought is evident, but the role of the individuals is perhaps less clear. There seems to be a suggestion that the whole is not reducible to its parts (or their properties), which is an understandable aspect of any version of quantum holism, but we should recall that already in his 1951 book, Bohm insisted that objects should be regarded as ‘incompletely defined potentialities that are developed when the object interacts with an appropriate system’ (Bohm 1951: 139). Now, Pylkkänen, Hiley, and Pättiniemi suggest that the resulting view comes close to Ladyman and Ross’s form of ontic structural realism, but if there is any hint about his later theory contained in Bohm’s 1951 passage, then a further interpretation may be available. What I have in mind is a view that could in fact be closer to moderate structural realism, as developed by Esfeld and Lam (2010). According to this type of structural realism, there can be a mutual ontological dependence between objects and structure (i.e., relations).

In fact, this comes close to what Pylkkänen, Hiley, and Pättiniemi (2015: 234) suggest themselves in reply to the criticism from Ladyman and Ross, namely, that properties like mass, charge, and so on reside both in the particle aspect and in the field aspect of the individual system. If this is the case, then it would be natural to regard them as mutually dependent. This is, perhaps, in contrast to some of the passages from Bohm and Hiley, but my question (to Paavo) here is this: just how important it is for the Bohm theory that the whole is prior to its parts? If all the relevant work can be done insofar as the parts

are dependent on the whole, then why could the whole not also be dependent on the parts? The resulting picture could still be regarded as a form of quantum holism. But if we go this far, a whole new area of research opens up, because we would surely wish to know more about the relationship between parts and wholes. But I leave a deeper discussion of these issues to my forthcoming work with Christina Conroy and Donnchadh O'Conaill (Conroy, O'Conaill, and Tahko ms.).

It remains to be concluded that the Bohm theory and Paavo's work in promoting it still have many fruits to bear, and it clearly has a separate life from the Bohmian mechanics approach.

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Reader in Metaphysics of Science, Department of Philosophy,  
University of Bristol, UK  
tuomas.tahko@bristol.ac.uk