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Still or Sparkling? Past, Present and Future in Bohm's Implicate Order Approach.

Paavo Pylkkänen
University of Helsinki and University of Skövde

"Time is Nature's way to keep everything from happening all at once."[1]

1. Introduction

David Bohm (1917-1992) was a physicist who published extensively on philosophical topics. He is particularly well known for proposing, after discussions with Einstein, the first consistent ontological interpretation of quantum theory (Bohm 1952 a & b; Bohm and Hiley 1987, 1993; Goldstein 2021).[2] But he was also trying to develop a much more ambitious scheme, a new framework or scientific world view in which one could hope to bring together quantum theory and (general) relativity, and include biological and psychological phenomena (Bohm 1980; Pylkkänen 2007). This new "implicate order" world view, combining process philosophy with structuralism, also implies a certain physics-based way to think about time, including how to understand past, present and future; being and becoming; and the nature of movement. Philosophical discussions of time sometimes take a one-sided view from physics, for example by emphasizing only the special theory of relativity. But a more accurate notion of time in physics should surely try to do justice to all fundamental theories in physics, especially quantum theory and (general) relativity. Bohm was one of those physicists in the latter half of the 20th century who truly struggled to bring out the philosophical (and especially ontological) implications of both quantum theory and relativity and attempted to

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[1] Discovered among graffiti in the men's room of the Pecan Street Café, Austin, Texas. Reported by John Wheeler (1990), p. 315.

[2] For a recent biography of Bohm, see Freire, O., Jr. (2019), who writes (p. vi): "The legacy of …. Bohm to physics may be stated in a nutshell: He was a physicist who made many and lasting contributions particularly in subjects such as plasma, metals, and quantum mechanics; he was one of the discoverers of the Aharonov–Bohm effect and suggested alternative interpretations of quantum mechanics. He was undoubtedly one of the major twentieth-century physicists. […] Bohm's main legacy in quantum mechanics, I think, was his contribution to keep [the interpretation debates in quantum mechanics] alive in times when many of physicists thought it should be closed." For a discussion of Bohm's 1952 interpretation of quantum theory and its relation to relativity, see Goldstein (2021), and Bohm and Hiley (1993).

E-mail: paavo.pylkkanen@helsinki.fi
Web: https://philpeople.org/profiles/paavo-pylkkanen

describe them in a more general way. In this short article I will present and discuss some of Bohm's ideas about time, hopefully helping philosophers of time to evaluate whether they could be helpful in tackling some of the difficult problems connected to our ideas about time (see also Limnell 2008).

2. Quantum mechanics challenges the block universe view and suggests extended, overlapping moments as the spatio-temporal building blocks of the universe

Bohm's implicate order scheme promises to give us the notion of the present moment as genuinely real and extended; the notion of the past as "enfolded" structures in the present moment (nested memories or reverberations or active transformations); and the notion of future as anticipated, "enfolded" potentialities that are actualized in a creative way in the present moment. This is a tall order. The first objection might come from the supporters of the block universe theory. Does not relativity theory say that space-time is a block, and time (in the sense of past-present-future, as well as genuine becoming) is an illusion? Bohm (1986: 183) argues that quantum mechanics strongly questions the foundations of the block universe view. First of all, he claims that the uncertainty principle of quantum mechanics implies that the point event of relativity theory (a key element of the block universe view) cannot in general have an unambiguous meaning. Even more radically, he suggests that Einstein's well-known photon-in-a-box experiment (when extended) implies a fundamental breakdown in the notion that the point event can be absolute.[3] Instead, Bohm says, quantum

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[3] An anonymous referee was concerned about the conflict between Bohm's view and the principles of relativity theory. I will not go into this question in detail in this paper, but I include a quote from Bohm's 1986 article, which provides more explanation. Note in particular that in Einstein's photon-in-a-box experiment the breakdown in the notion that the point event can be absolute is a consequence of the general theory of relativity (when we consider quantum indeterminacy in its light): "[A]ccording to modern physics, microprocesses are […] very fast, irregular, and ambiguously related to what comes next. Indeed, it is not in general possible to relate the specifiable information content unambiguously to succeeding events (this is just the essential meaning of the Heisenberg uncertainty relations, as interpreted by Bohr). Here, too, the relevance of the usual notions of time may be questioned. What seems to be called for is that we recognize that the ''point event'' of relativity theory cannot in general have an unambiguous meaning.

General relativity leads to this conclusion in an even more forceful way. There is Einstein's well-known hypothetical experiment of weighing a photon in a box. To make what is meant more vivid, imagine a box within which is a whole context of process determining a space-time order and measure appropriate to this context. This box is supported on a spring, which has a certain "quantum indeterminacy" or ambiguity in its height above the ground. It is then a consequence of the general theory of relativity that there is a minimum ambiguity or "uncertainty" in the relationship between the rates of processes inside the box and those outside, which latter are based on the more solid support of a firm foundation that does not move.

More generally, this relationship depends on the whole context. This constitutes a fundamental breakdown in the notion that the point event can be absolute." (Bohm 1986: 183) mechanics suggests that there exist objective but context-dependent moments which are extended in some sense and ambiguously located in space and time. The term “moment” should here be understood in the same sense as our actual experience of the moment “now”, as something that is never completely localizable in relation to other moments, while typically overlapping with them.[4] In the quantum mechanical domain, the extension and duration of a moment is dependent on the quantum mechanical wave function. Each moment is subject to a certain lack of precise localizability over a region in which the wave function is appreciable. (Ibid.: 184)[5]

This idea of moments in the physical universe is similar to our experienced moment of “now”, which is also extended and ambiguously located in space and time and internally related to other moments (e.g. overlapping with them, or enfolding information about them as memories). Bohm implies that we can assume that the present moment, with its extended spatio-temporal structure, is genuinely real. The past of a given present moment can be enfolded as a nested structure (e.g. a memory) that is present in that actual moment. Moments

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[4] For a thorough discussion of theories involving overlapping moments of temporal consciousness, see Dainton 2022. By suggesting that overlapping moments are the spatio-temporal building blocks of the physical world, Bohm (like Whitehead) opens up a new way to understand the relationship between conscious experience and the physical world.

[5] An anonymous referee was concerned about whether causal structure (essential for relativity) might be violated in Bohm’s view which includes extended and ambiguously located, overlapping moments. The way that Bohm deals with this is to suggest that ordinary space-time (and ordinary causality) emerge as a limiting case or approximation from the implicate order (or from what John Wheeler calls “pre-space” or “pre-geometry”). Quantizing gravity implies that for very short times and distances, the entire notion of space-time becomes totally undefined and ambiguous. Bohm (1986: 192) notes that Wheeler (1980) in particular has drawn attention to “… a fundamental ambiguity in the meanings of the terms that define not only the rates of clocks and the lengths of rulers, but also relationships of “before” and “after.”” Bohm further notes that “…such an inability to define "before" and "after" (along with the light cone itself) dissolves the entire conceptual basis on which our notions of space and time depend.” (1986: 192) Or as Wheeler (1990: 315) himself puts it: “What are we to say about that weld of space and time into spacetime which Einstein gave us in his 1915 and still standard classical geometrodynamics? On this geometry quantum theory, we know, imposes fluctuations […]. Moreover, the predicted fluctuations grow so great at distances of the order of the Planck length that in that domain they put into question the connectivity of space and deprive the very concepts of "before" and "after" of all meaning.” Wheeler’s solution was to characterize space-time as a kind of very fine foam out of which continuous space, time and matter emerge as approximations on the large-sale level. However, because the structure of the foam is given by quantum laws, Bohm thinks it is more accurate to characterize pre-space as a form of the implicate order: “My attitude is that the mathematics of the quantum theory deals primarily with the structure of the implicate pre-space and with how an explicate order of space and time emerges from it, rather than with movements of physical entities, such as particles and fields.” (1986: 192-3) In Bohm’s view, moments are projected from the implicate order, but they are typically projected in such a way that no violations of causality are possible.

are thus not isolated or merely externally related point events as in relativity theory but are instead internally related extended structures and processes.

So let us assume, for the sake of the argument, that the block universe view is mistaken, and that there exist, as Bohm suggests, extended moments, ambiguously located in space and time, overlapping with each other. How do we understand the past, the present and the future in this way of thinking? And what is this "enfoldment" or "implicate order" that Bohm is relying upon?

3. Time is Nature's way to keep everything from happening all at once: How does Bohm's glycerine tank do the job?

We always find ourselves in the present moment. But when this present moment ends, where does it go? And where does the next present moment come from? Somehow, we need to a have a present moment, but we also need to get rid of it after a while, to make room for the next present moment that is to come. How can we understand this? Can Bohm's implicate order scheme help here?

There is an analogy or a model which helps to illustrate how time can be understood in terms of the implicate order. For Bohm, time is an abstraction from process - time has to be abstracted from an ordered sequence of changes in an actual physical process (Bohm 1986: 189). We are now going to describe a physical process which can be used to illustrate past, present and future; it also provides a way to think about the present moment, what happens to it when it is gone, and how the new present moment comes into being. The model also illustrates how movement can be understood in a new way; and later on in the article we will even briefly show how the model can be used to describe particle creation and annihilation in quantum field theory without having to assume (as the usual view does) that particles are moving backwards in time. But please note that what we are going to describe is merely a model or analogy. It has some mechanical features in it which, for one thing, do not capture some important non-mechanistic features of the quantum processes. So please take the analogy with a Wittgensteinian grain of salt, as a scaffolding or ladder which is to be kicked away once it has helped you to understand the point it is trying to make.

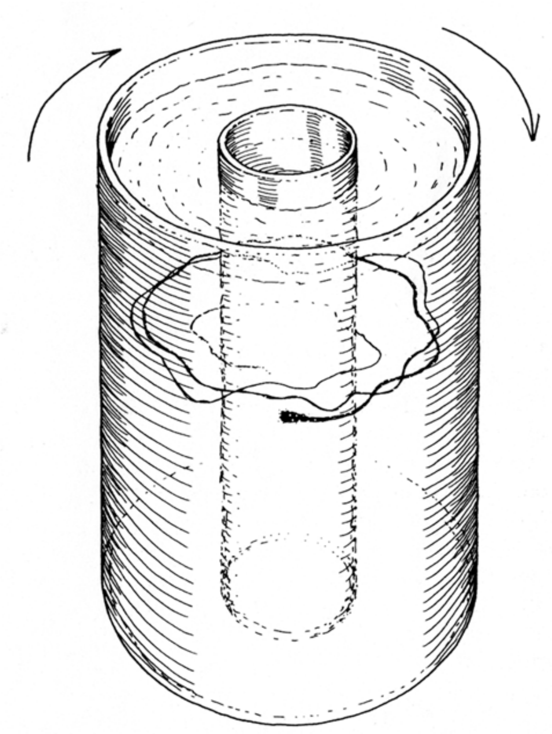

Figure 1: The ink-in-glycerin device

The analogy makes use of an apparently simple device: a tank made of two concentric glass cylinders filled with viscous fluid such as glycerine between them (see Figure 1).[6] The outer cylinder can be turned very slowly, which results in negligible diffusion of the fluid. Let us place a droplet of insoluble ink in the fluid and turn the outer cylinder. As we keep turning, the droplet is drawn out into a fine thread-like form that eventually becomes invisible. However, when we turn the outer cylinder in the opposite direction, the thread-like form draws back and suddenly becomes visible, as a droplet essentially the same as the original one (Bohm 1980, p. 179).

How can we use this device to model past, present and future? Let us say that when we put the droplet to the glycerine, and do not turn it, it represents the the present moment, the state of the universe at the present time t. When we then turn the outer cylinder, the droplet is drawn out until it becomes invisible. It still exists in the present moment, but not as

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[6] For a link to a *New Scientist* video of this device, see https://transitionconsciousness.wordpress.com/2015/09/19/the-experiment-which-inspired-david-bohm/ In this particular model the inner (rather than the outer) cylinder is turned. Bohm first saw this device when watching a BBC television programme and made extensive use of it in his 1980 book *Wholeness and the Implicate Order*.

a visible entity. Bohm would say that the droplet has become "enfolded" into the whole glycerine, analogously to the way an egg is folded into the dough when we are preparing a cake.[7] If we think this as a model or time, we can say that what was previously the present moment has been enfolded. It exists in some sense in the present moment, but not in the same way as the original droplet. The original droplet, before turning, was in an unfolded or "explicate" state, while after turning, the droplet is in an enfolded or "implicate" state. Now, let us say that the present moment corresponds to the explicate, and the past to the implicate.

Can we use this device to model the future? To get started with this, let us make a very simplifying assumption that we know what the future will be like. To make a model of past-present-future, I will start with the device in a state where no droplets have yet been placed. First of all, I will put in the glycerine a droplet which represents the state of the universe at the most distant future I want to model. I then turn n times, until the droplet is enfolded. I then put in a droplet which represents the state of the universe at a slightly earlier time in the future and turn n times (which means that the droplet I put in first has been enfolded 2n times). I keep on doing this until a great number of droplets have been enfolded. I finally put in the last droplet, and do not turn. Let us say that this last droplet which is unfolded and visible represents the present moment. Now I can start turning the outer cylinder to the opposite direction. The droplet that represents the present moment begins to be drawn out into a fine thread-like form; it will be enfolded and becomes the past. But as I keep turning, the last of the droplets I put in and used to model the future becomes visible first as a thread-like form which draws back and then becomes visible as a droplet. This droplet, which was previously enfolded and represented a future moment, has now become unfolded and represents the present moment. But if I keep turning, this droplet will in turn re-enfold and becomes a representation of the past, making room for the next droplet which will unfold and represent the present.

So here we have a very simple way of thinking about the past, the present, and the future. The present moment is represented by the droplet that is currently unfolded and visible; the past moments are represented by droplets that have been enfolded n, 2n, 3n etc

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[7] We are dealing with an enfolded or "implicate" order here. Note also that this is a very special kind of enfolded order because we can unfold it back to where we started from, because of the reversibility made possible by the properties of glycerine. In contrast, once we have folded the egg to the dough, we will not get it back by reversing the motion of the whisker, because in that situation the egg has undergone irreversible diffusive mixing. There is a sense in which the egg in the dough still exists as an enfolded structure, but for all practical purposes we have lost the possibility of unfolding it.

times. The future moments are likewise represented by droplets that have been enfolded n, 2n, 3n etc. times.

There is a sense in which the past, the present and the future all exist. But they do not exist in the same way. As we mentioned, the model gives a very simplified picture. For example, the way we have used it implies that the future is determined, existing as well-defined enfolded structures, which will unfold mechanically into successive present moments. Bohm actually thought that the future exists as potentialities, and that the way these potentialities unfold or become explicate in the present can involve genuine creativity. So it is clear that the scheme has to be developed to allow for this (see Bohm 1986; for a more technical discussion see Bohm 1987; for a recent discussion of Bohm's notion of potentiality in the context of theology, see Korpela 2022).

4. Movement understood in terms of the implicate order

We can use this device also to model movement. To do this, let us insert a droplet, A, in a certain position and turn the cylinder n times. Then we insert a droplet, B, in a slightly different position and turn the cylinder n more times (so that A has been enfolded by 2n turns). And then we insert C along the line AB and turn the cylinder n more times, so that A has been enfolded by 3n turns, B by 2n turns, and C by n turns. We proceed in this way to enfold a large number of droplets. Then we move the cylinder fairly rapidly in the reverse direction. If the rate of emergence of droplets is faster than the minimum time of resolution of the human eye, what we will see is apparently a particle moving continuously and crossing the space. But in this analogy, there is no such single particle. What we have is a set of co-present elements ("droplets") at different degrees of enfoldment, giving rise to the appearance of a particle moving continuously. This is a key characteristic and assumption of the implicate order theory: movement typically involves set of co-present elements at different degrees of enfoldment.

Bohm thinks, radically, that moments of conscious experience and moments of physical reality are analogous to each other. We can experience movement in conscious experience, and we also assume that there is movement in the physical world, taking place independently of the human mind. He suggests that in both cases the nature of movement is similar in some important respects. What does he mean by that?

As an example he discusses our experience when we are watching a motion picture, say a short part of a film where a car is moving. The input consists of a set of discrete images which are typically slightly different from each other. If the time interval between the images is short enough, we will experience movement in our conscious experience (i.e., we see a car moving). How does this come about? We might assume that the distinct images are processed in the brain, enfolded as it were, but yet retain their identity in some sense. Somehow all the images, although different, are sensed together, and this sensing, Bohm suggests, constitutes or gives rise to our conscious experience of movement. As we saw with the glycerine tank, a key feature of an implicate order is that there are "co-present elements at different degrees of enfoldment". The image that is first perceived "now" has the lowest degree of enfoldment (it is most explicate, cf. Husserl's primary impression), while the images that were perceived earlier have been slightly enfolded, and thus have a higher degree of enfoldment (cf. Husserl's retention). We typically also anticipate the images to come; perhaps such anticipations can be understood as implicit, enfolded, not fully explicate structures (cf. Husserl's protention). Thus, we can understand our experience of movement in consciousness by assuming that there are distinct neural representations in the brain, at different stages of processing (or "enfoldment") and that when these are sensed together, a sense of movement arises in conscious experience.[8] [9]

How is the above analogous to movement in the physical world? Think again about the glycerine tank, and the case where we placed a droplet in a certain location and turned the outer cylinder n times to enfold it, then a second droplet in a very nearby location, enfolding

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[8] Another example of the implicate order in conscious experience is listening to music. We hear certain notes for the first time in a given moment. Some of the notes that we have already heard earlier are present in our experience as active transformations rather than memories. Typically their degree of enfoldment is greater the more time has passed but they are still present. The future is present in the experience as anticipated notes. Just as with the example of the motion picture, sensing the neural representations of the co-present tones at different degrees of enfoldment gives rise to subtle sense of movement (e.g. the movement of a symphony) Bohm (1980). Pylkkänen (2007, ch 5) has applied the notion of implicate order to describe time consciousness and related it to e.g. Husserl's views (see also Hautamäki 2021).

[9] It would also be interesting to compare Bohm's view of movement in relation to the currently prominent approach to modelling perception, namely predictive processing (see Clark 2013). This approach assumes that perception is not merely a passive process in which information about the environment is received and processed until it gets experienced. Rather, what is important is that the brain is able to apply a hierarchical generative model which enables it to predict the unfolding (incoming) sensory stream. Presumably in this approach our experience of movement is assumed to be constituted more of the properties of the predictive model, than from the elements in the unfolding sensory stream. Whether the implicate order could be used to explain how the experience of movement arises in the predictive processing framework is a question worth exploring in future research.

it in a same way, and then a third one along the line defined by the two previous ones etc. etc. When we turn back quickly enough, it appears to us as if there is a "particle" moving in a straight line. Now, Bohm proposes this provides a rough model that to some extent illustrates what an electron is and how it moves. We will consider this idea in more detail in the next section.

5. Enfoldment and unfoldment in quantum field theory

Bohm's radical suggestion is that a certain kind of enfoldment and unfoldment (which we have described in a simple and mechanical way above with the device) is actually taking place in the physical universe and is indeed the universal and fundamental feature of physical law. He points out that according to quantum field theory all the elementary particles and atoms out of which chairs, tables, brains, bodies and other physical objects consist are structures that are enfolded in principle throughout all space (1980: 209). Analogously to the visible droplets we see unfolding and enfolding in the glycerine tank model, what we call "particles" are momentary particle-like manifestations that constantly and very rapidly unfold and enfold from an implicate order that prevail in the movement of quantum fields. This is how Bohm himself describes the general picture:

> "Because the implicate order is not static but basically dynamic in nature, in a constant process of change and development, I called its most general form the holomovement. All things found in the unfolded, explicate order emerge from the holomovement in which they are enfolded as potentialities and ultimately they fall back into it. They endure only for some time, and while they last, their existence is sustained in a constant process of unfoldment and re-enfoldment, which gives rise to their relatively stable and independent forms in the explicate order." (1990: 273)

The enfolding-unfolding notion was inspired by a mathematical technicality, namely the Green's function approach to Schrödinger's equation. Feynman showed that in quantum mechanics one can use the Huygens' construction to determine the wave function at a point y from the wave function at {x}, where {x) is the set of points on a surface at a previous time (Hiley and Peat 1987: 23). This can be expressed as:

$$\psi(y,t_2) = \int_{\text{surface}} M(x,y,t_1,t_2)\psi(x,t_1)\mathrm{d}x$$

Where $M(x,y,t_1,t_2)$ is a Green's function. The wave function at all points of the surface S contributes to the wave function at *y*. Thus, we can say the information on the surface S is enfolded into $\psi(y)$.

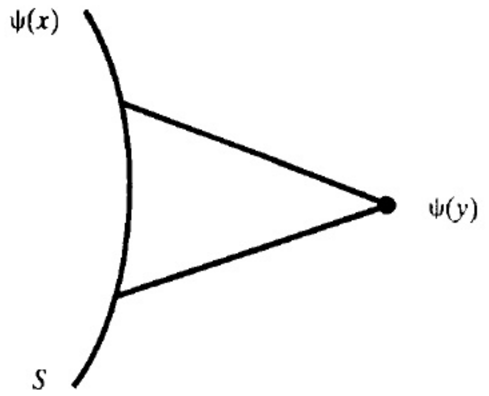

Figure 2: The information on the surface *S* is enfolded into $\psi(y)$

From this $\psi(y)$ one can calculate the probability of finding the particle at the location *y*. Thus we can say that the probability depends on the enfolded information of a set of earlier wave functions. In this way, via enfoldment, the probabilities that prevail in the present moment in a given location depend on earlier wave functions.[10] The past constrains the probabilities of the present.

In turn, $\psi(y)$ itself gets 'unfolded' into a series of points on a later surface *S'*.

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[10] In Bohm and Hiley's (1987) ontological interpretation of quantum theory, based on Bohm's 1952 "hidden variable" theory (which we are not discussing in this paper), the $\psi(y)$ determines the so-called quantum potential acting on the particle at *y* so that the particle reacts to the enfolded information of a set of earlier wave functions. So in this model not just the probability but also the actual behaviour of the quantum object depends in a holistic way (via enfoldment) upon earlier wave functions. See Hiley and Peat 1987: 23.

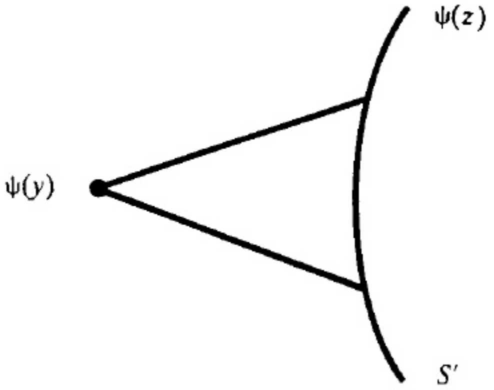

Figure 3: $\psi(y)$ gets 'unfolded' into a series of points on a later surface *S'*

Now, if we assume that the wave function is a complete description of the electron (as is often done in the usual interpretation of non-relativistic quantum theory) then the mode of being of an electron can be assumed to be a movement of unfoldment and enfoldment of the wave function.

Bohm and Hiley discuss the way the implicate order and quantum field theory are related in the last chapter of their 1993 book *The Undivided Universe*, noting that the Huygens' construction exemplifies the implicate order and is the basis of the Feynman graphs which are widely used. They point out that all matter is now analysed in terms of quantum fields and note that the movements of all these fields are expressed in terms of propagators (used to calculate probability amplitudes for particle interactions using Feynman diagrams.) Thus, they argue that current physics implies that the implicate order is universal (Bohm and Hiley 1993: 355-6).

To make more clear the connection between the implicate order and Feynman diagrams, they use the glycerin tank model (see above, sections 3 and 4) to illustrate pair production and annihilation (see Figure 4). To model pair production, one needs to put in the droplets in such a way, that when one turns the cylinder in a certain direction, it will appear that two particles emerge at a single region, and then start moving in different directions. To model annihilation, one needs to put in the droplets in such a way, that when one turns the cylinder in a certain direction, two particles appear to come toward the same point from different directions, and then disappear.

Bohm and Hiley (1993: 359) describe how to do this. One first enfolds the droplets one by one, placing them at a constant distance from each other (marked by N in Figure 4). One then reverses the movement of the cylinder to enfold additional droplets (marked by S in Figure 4). Finally, one turns the cylinder in the original direction and then enfolds further droplets in a similar way. When the cylinder is then turned backwards, one will see a "particle" moving from the left toward point Q. At the point P there will suddenly appear a pair of particles moving in different directions and one of these will proceed to meet the original particle at the point Q. They then appear to annihilate each other, while the other member of the original pair will proceed onwards to the left (N).

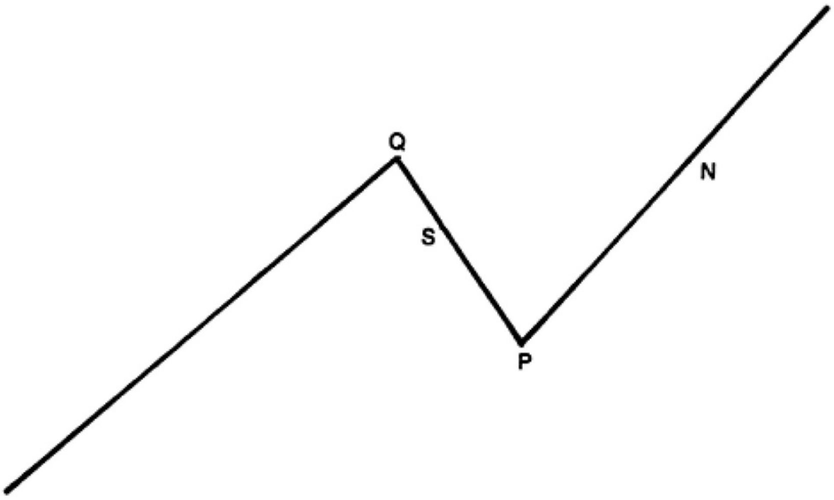

Figure 4: Enfoldment and pair creation.

Let us compare the above example to a Feynman diagram which describes a somewhat similar situation. In the Feynman diagram shown below, an electron (**e^-**) and a positron (**e^+**) annihilate, producing a photon (**γ**, represented by the sine wave) that becomes a quark-antiquark pair (quark **q**, antiquark **q̄**), after which the antiquark radiates a gluon (**g**, represented by the helix). Note that the positron (**e^+**) and the antiquark (**q̄)** are moving backwards in time!

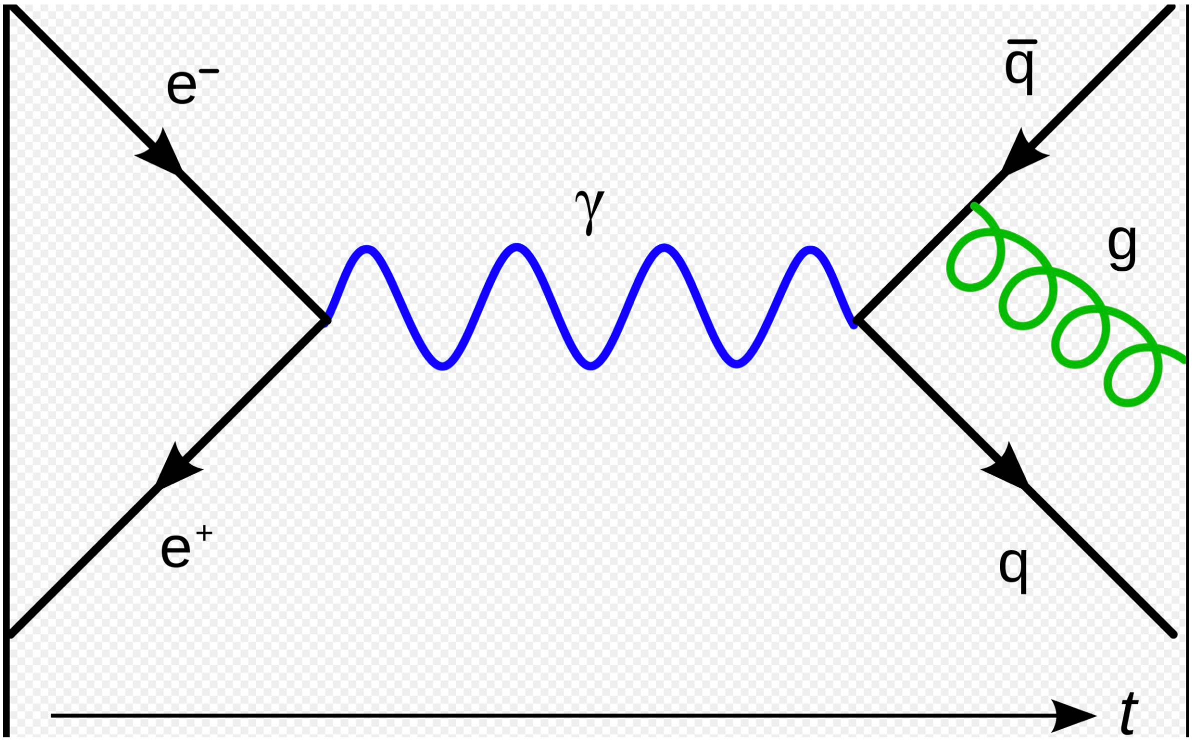

Figure 5: A Feynman diagram showing the radiation of a gluon when an electron and positron are annihilated. Source: *Wikipedia*.

Note, however, that unlike the representation given in the Feynman diagram, Bohm and Hiley do not say in their example that anything 'moves' backward in the time. Rather, they emphasize that what is significant is the order in the degree of implication.

They define an implication parameter, **τ** , of a droplet, which is proportional to the number of times the cylinder has been turned since that droplet was inserted:

> "This implication parameter takes negative values when the cylinder is turned in the opposite direction. What happens in this example is that the implication parameter has a part that increases, another part in which it decreases and a third part in which it increases again. The entire pattern is present at each instant in the whole fluid with varying degrees of implication. All that happens with the passage of time is a change in the implication parameter which may be positive or negative." (Ibid.: 360)

They then suggest that what is called the time coordinate in the Feynman approach may actually be the degree of implication:

> "In this interpretation, Feynman diagrams would not refer to actual processes but rather to structures in the implicate order. The meaning of time would then be something different from $\boldsymbol{\tau}$ but nevertheless related to it." (Ibid.: 360)

So the key point is that to explain particle creation and annihilation, it is not necessary to assume that particles move backwards in time. Physical processes involve implication and explication, enfoldment and unfoldment, but this does not require that anything moves backwards in time. What is characteristic of each "elementary particle" is its degree of implication, which, as time passes, determines the way it will appear in experimental situations, and how it appears to interact with other particles. Bohm and Hiley's model in a sense saves our usual notion of time, and draws attention to a new basic feature, unfoldment and enfoldment, which can be parametrized.

6. Concluding remarks

We saw above that there is a conservative element to Bohm and Hiley's approach. While Feynman is happy to propose radically that the positron ($\mathbf{e}^+$) and the antiquark ($\bar{\mathbf{q}}$) are moving backwards in time, this conclusion can be avoided in implicate order with its notion of enfoldment.

Note also the structuralist spirit of Bohm and Hiley's discussion. They draw attention to the "entire pattern" that is present at each instant in the whole fluid with varying degrees of implication. And unlike what is commonly thought, they suggest that Feynman diagrams do not describe actual processes but rather structures in the implicate order. In another context Bohm would characterize this structural aspect as the "being of becoming" (1986: 185, 197). While he is happy to assume that there is genuine becoming (i.e., "becoming of being"), he also assumes that there is an underlying timeless structure that is essential to becoming (this is the "being of becoming"). The above way of describing quantum field theoretical processes in structuralist terms is similar to Bohm's description of our experience of movement when watching a motion picture (see section 4 above). While our experience is that of continuous movement, Bohm explains it structurally as grounded in "co-present elements at different degrees of enfoldment" in the brain. Thus, whenever there is something that is "sparkling" (i.e. whenever there is movement in conscious experience or in the physical world), there is also something that is “still” (e.g. the structures in the implicate order that make movement possible).[11]

Figure credits: Cindy Tavernise: Figure 1; Basil J. Hiley: Figures 2, 3 and 4; *Wikipedia* (public domain): Figure 5.

References

Bohm, D. 1952a & b. “A Suggested Interpretation of the Quantum Theory in Terms of Hidden Variables I & II”. *Physical Review* 85:66-179 and 180-193.

Bohm, D. 1980. *Wholeness and the Implicate Order.* London: Routledge.

Bohm, D. 1986. “Time, the implicate order, and pre-space”. In *Physics and the Ultimate Significance of Time: Bohm, Prigogine and Process Philosophy*, edited by D. Griffin, 177-208. Albany: State University of New York Press.

Bohm, D. 1987. “The Implicate Order and Prigogine’s notion of irreversibility.” *Foundations of Physics* 17: 667-677.

Bohm, D. 1990. “A New Theory of the Relationship of Mind and Matter.” *Philosophical Psychology* 3(2): 271-286.

Bohm, D. and B. J. Hiley 1987. “An Ontological Interpretation of Quantum Theory.” *Physics Reports* 144(6): 321-375.

Bohm, D. and B. J. Hiley. 1993. *The Undivided Universe: An Ontological Interpretation of Quantum Theory*. Routledge: London.

Clark, A. 2013. “Expecting the World: Perception, Prediction, and the Origins of Human Knowledge.” *The Journal of Philosophy* CX, 9: 469-496.

Dainton, B. 2022. ”Temporal Consciousness”. *The Stanford Encyclopedia of Philosophy* (Summer 2022 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/sum2022/entries/consciousness-temporal/

Freire, O., Jr. 2019. *David Bohm, a life dedicated to understanding the quantum world.* Berlin: Springer.

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[11] I have borrowed the expression ”Still or sparkling?” and part of the title of this paper from the title of section 3.7.1 in Ladyman & Ross’ (2007) book *Everything Must Go: Metaphysics Naturalized*, where they discuss the metaphysics of time. Chapter 3 of that book is an excellent discussion of issues in philosophy of physics, even though the possibility of the individuality of quantum objects is dismissed a little too strongly. See Pylkkänen et al. (2016).

Goldstein, S. 2021. “Bohmian Mechanics”. *The Stanford Encyclopedia of Philosophy* (Fall 2021 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/fall2021/entries/qm-bohm/

Hautamäki, A. 2021. “Aika ja aikatietoisuus” [”Time and time consciousness”], In *Unfolding the Big Picture: Essays in Honour of Paavo Pylkkänen,* edited by P. Limnell ja T. Vadén. Helsinki: Philosophical Studies from the University of Helsinki 50. English version: https://www.researchgate.net/publication/359867312_Time_and_Time_Consciousness_2

Hiley, B.J. and Peat, F.D. 1987. “General introduction: The development of David Bohm's ideas from the plasma to the implicate order”. In *Quantum Implications: Essays in Honour of David Bohm*, edited by B.J. Hiley and F.D. Peat. London: Routledge.

Korpela, S. 2022. *God, Time and the Concept of Potentiality in Quantum Physics.* Doctoral dissertation, University of Helsinki. Available at: https://helda.helsinki.fi/handle/10138/346531

Ladyman, J. and Ross, D. (with D. Spurrett and J. Collier). 2007. *Every Thing Must Go: Metaphysics Naturalized.* Oxford: Oxford University Press.

Limnell, P. 2008. “*HIC & NUNC* – Nyt-hetken analyysia fysiikan, metafysiikan ja tajunnantutkimuksen näkökulmista.” [“*HIC & NUNC* – Analysis of the moment now from the perspectives of physics, metaphysics and consciousness studies.”] Pro gradu (Masters) thesis, University of Tampere.

Pylkkänen, P. 2007. *Mind, Matter and the Implicate Order*. Berlin: Springer.

Pylkkänen, P., Hiley, B. J. and Pättiniemi, I. 2016. ”Bohm’s approach and individuality.” In *Individuals Across the Sciences,* edited by A. Guay, A. and T. Pradeu, 226-249. Oxford: Oxford University Press. http://arxiv.org/abs/1405.4772

Wheeler, J.A. 1980. “Pregeometry: Motivations and Prospects.” In: A. R. Marlow, Ed., *Quantum Theory and Gravitation*. New York: Academic Press, pp. 1-11.

Wheeler, J. 1990. “Information, Physics and Quantum: The Search for Links.” In *Complexity, Entropy and the Physics of Information,* edited by W.H. Zurek. Redwood City, Calif: Addison-Wesley.