DAVID JOSEPH BOHM: 1917–1992

DETLEF DÜRR,[1] SHELDON GOLDSTEIN,[2] AND NINO ZANGHÍ[3]

David Bohm, Emeritus Professor of Theoretical Physics at Birkbeck College of the University of London and Fellow of the Royal Society, died of a heart attack on October 29, 1992 at the age of 74.

Professor Bohm had been one of the world's leading authorities on quantum theory and its interpretation for more than four decades. His contributions have been critical to all aspects of the field. He also made seminal contributions to plasma physics. His name appears prominently in the modern physics literature, through the *Aharonov-Bohm effect*, the *Bohm-EPR experiment*, the *Bohm-Pines collective description of particle interactions (random phase approximation)*, *Bohm diffusion* and the *Bohm causal interpretation of quantum mechanics*, also sometimes called the *de Broglie-Bohm pilot wave theory*.

David Bohm was born in Wilkes-Barre, Pennsylvania on December 20, 1917. A student of J. Robert Oppenheimer, Bohm received his Ph.D. from the University of California at Berkeley in 1943. In 1950 he completed the first of his six books, *Quantum Theory*, which became the definitive exposition of the orthodox (Copenhagen) interpretation of quantum mechanics. Here Bohm presented his reformulation of the paradox of Einstein, Podolsky, and Rosen. It is this Bohm version of EPR which has provided the basis for the enormous expansion of research on the foundations of quantum theory, focusing on nonlocality and the possible incompleteness of the quantum description (the question of "hidden variables"), which has occurred during the past several decades.

[1]Fakultät für Mathematik, Universität München, Theresienstrasse 39, 8000 München 2, Germany.
Supported in part by DFG.
[2]Department of Mathematics, Rutgers University, New Brunswick, NJ 08903.
Supported in part by NSF Grant No. DMS–9105661.
[3]Istituto di Fisica, Università di Genova, INFN, Via Dodecaneso 33, 16146 Genova, Italy.
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The first major step in this research was made by Bohm and Aharonov in a remarkable 1957 paper, in which they demonstrate the existence of a "rather strange kind of correlations in the properties of distant things." This paper was a forerunner of the seminal "Bell's theorem" paper of 1965, which considerably sharpened the Bohm-Aharonov result: Bell demonstrated that "nonlocality" was a consequence of the *predictions* of quantum theory, predictions which were confirmed by Aspect in 1983.

In 1959, Bohm again collaborated with Aharonov, this time on a paper concerned with a very different sort of nonlocality. The result was the Aharonov-Bohm effect: a magnetic field can influence the behavior of electrons confined far away from the field, something incompatible not only with classical physics but with the spirit of the *orthodox* interpretation of quantum theory as well. The Aharonov-Bohm effect remains, some three decades after its discovery, a subject of intense research: it is of profound significance to a wide range of areas of physics, from foundations to micro-electronics, from superconductivity to mesoscopic quantum effects, and from fractional statistics to nonlocal effects in metals.

In 1990 Bohm was elected Fellow of the Royal Society. He was awarded the Franklin Institute's Elliot Cresson Medal in 1991.

We focus here on Bohm's contributions to physics. However, he also made profound contributions to many other disciplines: to the philosophy of science and the philosophy of mind, to ethics and moral philosophy. And Bohm labored long for peace and disarmament, for dialogue and mutual understanding.

Richard Feynman once declared Bohm the smartest man he had ever met. He was certainly a man of extraordinary commitment to principle, both scientific—as witnessed by his often lonely pursuit of scientific truth, without regard for prevailing fashion—and moral—as witnessed by his refusal in 1951 to testify against colleagues before the House Un-American Activities Committee, an act which led to his indictment for contempt of Congress and his banishment from Princeton and, indeed, from all of American academia.

We now turn to Bohm's greatest achievement, what he called the causal interpretation of quantum theory but what would be more aptly regarded—as we have elsewhere argued—as a new, radically non-Newtonian mechanics, *Bohmian mechanics*. We remind the reader that a theory such as Bohm's, a fully deterministic alternative to the prevailing Copenhagen interpretation of quantum theory, had been regarded for several decades not merely as implausible but, on the authority of Bohr and von Neumann, as impossible.

Bohm's theory is connected, in an ironic sort of way, with John Stewart Bell and Bell's celebrated theorem, which has been widely cited in support of quantum orthodoxy. We therefore think it would be appropriate to use Bell's words to complete this scientific eulogy, particularly since Bell would now be writing to honor the memory of David Bohm were it still possible.

> In 1952 I saw the impossible done. It was in papers by David Bohm. Bohm showed explicitly how parameters could indeed be introduced, into nonrelativistic wave mechanics, with the help of which the indeterministic description could be transformed into a deterministic one. (*Speakable and unspeakable in quantum mechanics*, Cambridge University Press, 1987, p. 160) ... Bohm's 1952 papers on quantum mechanics were for me a revelation. The elimination of indeterminism was very striking. But more important, it seemed to me, was the elimination of any need for a vague division of the world into "system" on the one hand, and "apparatus" or "observer" on the other. I have always felt since that people who have not grasped the ideas of those papers...and unfortunately they remain the majority...are handicapped in any discussion of the meaning of quantum mechanics. (*Speakable and unspeakable*, p. 173)

The "parameters" to which Bell referred, which have frequently been called "hidden variables," are merely the *positions* of the particles of the quantum system. Shortly before discovering his famous theorem, while analyzing the behavior of such a system under Bohmian mechanics, Bell noticed that

> in this theory an explicit causal mechanism exists whereby the disposition of one piece of apparatus affects the results obtained with a distant piece.... Bohm of course was well aware of these features of his scheme, and has given them much attention. However, it must be stressed that, to the present writer's knowledge, there is no *proof* that *any* hidden variable account of quantum mechanics *must* have this extraordinary character. It would therefore be interesting, perhaps, to pursue some further "impossibility proofs," replacing the arbitrary axioms objected to above by some condition of locality, or of separability of distant systems. (*Speakable and unspeakable*, p. 11)

In an interview a few years ago with the philosopher Renée Weber, Bell elaborates:

> When I first realized that [Bohm's theory is nonlocal], I asked: "Is that inevitable or could somebody smarter than Bohm have done it differently and avoided this nonlocality?" That is the problem that [Bell's] theorem is addressed to. The theorem says: "No! Even if you are smarter than Bohm, you will not get rid of nonlocality," that *any sharp mathematical* formulation of what is going on will have that nonlocality....
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> In my opinion the picture which Bohm proposed then completely disposes of all the arguments that you will find among the great founding fathers of the subject—that in some way, quantum mechanics was a new departure of human thought which necessitated the introduction of the observer, which necessitated speculation about the role of consciousness, and so on.
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> All those are simply refuted by Bohm's 1952 theory.... So I think that it is somewhat scandalous that this theory is so largely ignored in textbooks and is simply ignored by most physicists. They don't know about it.

It is of course not too late to learn, but now we shall have to find our way alone.