The Undivided Universe: An Ontological Interpretation of Quantum Theory

David Bohm and Basil J. Hiley
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With the possible exception of John Bell, no physicist has contributed more than David Bohm to the past four decades' revitalization of research on the interpretation and foundations of quantum theory. Written with his long-time collaborator Basil Hiley and completed shortly before his death in 1992, this volume represents Bohm's final thoughts on this notoriously difficult subject.

The ontological interpretation in the book's subtitle refers to the causal interpretation of quantum mechanics, a refinement and completion of de Broglie's 1926 pilot-wave model of non-relativistic quantum theory proposed by Bohm in 1952 and now more frequently called Bohmian mechanics. This theory inherits and makes explicit the nonlocality implicit in the notion, common to just about all formulations and interpretations of quantum theory, of a wave function on the configuration space of a many-particle system. It is this nonlocality, this aspect of wholeness, to which the main title refers.

In Bohmian mechanics, a system of particles is described in part by its wave function, evolving, as usual, according to Schrödinger's equation; the description of the system is completed by the specification of the actual positions of the particles. The latter evolve according to Bohm's "guiding equation," which expresses the velocities of the particles in terms of the wave function. Thus, in Bohmian mechanics, the configuration of a system of particles evolves via a deterministic motion choreographed by the wave function. In particular, when a particle is sent into a double-slit apparatus, the slit through which it passes and where it arrives on the photographic plate are completely determined by its initial position and wave function.

In view of what is so often said about the radical implications of quantum theory, it should be somewhat surprising to learn that Bohmian mechanics in fact works: It accounts for all nonrelativistic quantum phenomena. In particular, the usual measurement postulates of quantum theory, including collapse of the wave function and probabilities given by the absolute square of probability amplitudes, emerge as a consequence merely of the two equations of motion—Schrödinger's equation and the guiding equation—without the traditional invocation of a special and somewhat obscure status for observation. The bulk of this book is devoted to providing a detailed, and for the most part quite convincing, exposition of how this comes about.

In one respect, however, Bohm and Hiley are not radical enough: They formulate Bohmian mechanics in terms of the "quantum potential," which permits the guiding equation to be recast into a classical, Newtonian form, but at the price of obscuring the basic structure and the defining equations of the theory and of injecting an appearance of artificiality into its formulation. The quantum potential plays a genuine role only in their analysis of the classical limit; elsewhere, it is the wave function and the (original) guiding equation that are relevant. Their treatment of spin is not entirely satisfactory: The extension of Bohmian mechanics to a system of particles with spin is immediate, requiring none of the complications encountered in the book's presentation. Recent important developments in the analysis of the origin of randomness in a Bohmian universe are unfortunately omitted. There are too many errors in the equations. The speculations in the last chapter about the "implicate order" don't enhance our understanding of Bohmian mechanics; on the contrary, before the reader has had time to digest this theory, he is given the impression that it depends upon these speculations for its adequacy.

Despite these and other reservations, I believe that this is a brilliant book, of great depth and originality. Clearly written, it provides an unusually incisive account of quantum phenomena. Most of the major alternatives, such as the Copenhagen interpretation and the many-worlds interpretation, are presented and discussed, and while some of the criticisms of the proposals of Murray Gell-Mann and James Hartle concerning decohering histories are not on target, the treatment of these alternatives is, for the most part, open-minded, generous and genuinely illuminating. Every physicist and physics student who wants to understand quantum mechanics should read this book.

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