perspective enunciated here is not only utterly alien to those with political power but rarely encountered even in what passes for enlightened talk in these dangerous times. Nor is Gell-Mann overly sanguine about the prospects: "We are all in a situation that resembles driving a fast vehicle at night over unknown terrain that is rough, full of gullies, with precipices not far off. Some kind of headlight, even a feeble and flickering one, may help to avoid some of the worst disasters." In a very general sense, I would characterize this as a book of headlights.

The Undivided Universe: An Ontological Interpretation of Quantum Theory

David Bohm
and Basil J. Hiley
Routledge, New York, 1993.
397 pp. $29.95 hc
ISBN 0-415-06588-7

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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Wrinkles in Time

George Smoot
and Keay Davidson
Morrow, New York, 1993.
325 pp. $25.00 hc
ISBN 0-688-12330-9

Through a Universe Darkly

Marcia Bartusiak
HarperCollins, New York, 1993. 400 pp. $27.50 hc
ISBN 0-06-18310-1

These two books concern the two biggest questions in modern cosmology: the initial conditions for structure formation in the universe and the nature of the dark matter. Both books are aimed at a general readership, and both are gracefully written.

Wrinkles in Time tells the story of George Smoot's quest to see structure in the cosmic background radiation. The real story begins with his group's observations in the late 1970s of the dipole anisotropy in the CBR temperature. (If space is filled with thermal radiation, there is at each point a special reference frame in which the temperature is isotropic. An observer moving with respect to this "CBR rest frame" sees a thermal spectrum in each direction but with a dipole anisotropy in the temperature: hotter in the forward direction and cooler in the backward direction.) The story's climax is the detection, announced in April 1992, of the quadrupole and higher multipole "wrinkles" in the CBR by the Differential Microwave Radiometer, one of the three instruments on the Cosmic Background Explorer satellite.

The emphasis in *Wrinkles in Time* is on the more adventurous aspects of Smoot's career—Smoot as the Indiana Jones of astrophysics. My favorite example: how Smoot and his former student Phil Lubin were al-