taking a course on liquid crystals.

Some minor shortcomings appear in the text. One concerns the presence of numerous grammatical mistakes and misspellings. Those never rise to the level of causing confusion, but they are noticeable. The second concerns a slight unevenness in how much background physics is supplied for the myriad topics covered in the book. In most cases, Blinov nicely relates his topic to basic physics before developing the ideas important to liquid crystals. But sometimes he makes a connection to a fairly sophisticated idea; in such cases readers unfamiliar with the concept will wish the author had offered a more fundamental discussion. But the weaknesses are fairly inconsequential; *Structure and Properties of Liquid Crystals* is a truly useful addition to the pedagogical literature on liquid crystals.

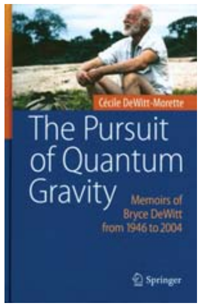
The Pursuit of Quantum Gravity

Memoirs of Bryce DeWitt from 1946 to 2004

Cécile DeWitt-Morette
Springer, New York, 2011. $49.95 (151 pp.). ISBN 978-3-642-14269-7

It took great courage for 24-year-old Bryce DeWitt, who in 1947 had just retired as a US Navy pilot in World War II, to choose a self-energy quantum gravity problem for his PhD thesis. When DeWitt entered graduate school that year at Harvard University where he studied under Julian Schwinger, quantum gravity was a peripheral field in physics and not a critical focus as it is now. In *The Pursuit of Quantum Gravity: Memoirs of Bryce DeWitt from 1946 to 2004*, DeWitt's wife Cécile DeWitt-Morette presents an honest and authoritative account of his remarkable contributions to the quantization and renormalization of the gravitational field and of non-abelian gauge fields, both of which are central today in particle physics.

DeWitt-Morette, a prominent physicist in her own right, is professor emerita at the University of Texas at Austin. *The Pursuit of Quantum Gravity* contains her well-chosen selection of DeWitt's original writings—their clarity highlights his extraordinary insight—and many personal recollections that capture his adventurous nature. Her own commentary on his writings is enlivening and sheds even greater light on his lifelong dedication to solving the problems of quantum gravity. She and DeWitt met in 1950 while both were conducting postdoctoral research at the Institute for Advanced Study in Princeton, New Jersey. They married in 1951 and moved to the University of North Carolina at Chapel Hill in 1956; there, encouraged by Freeman Dyson and John Wheeler, DeWitt would become the founding director of the Institute of Field Physics. (It was at the institute that Peter Higgs, then a postdoc, wrote his famous 1964 paper on the Higgs boson and its role in spontaneous symmetry breaking.) The DeWitts moved to the University of Texas at Austin in 1971 where he remained until his passing in 2004.



DeWitt was the first to find the perturbation rules to all orders for ghost fields, which are used to cancel infinities in internal loops but do not appear as external observable particles. In a 1988 letter reprinted on page 52, DeWitt wrote concerning his PhD thesis, "Since [an earlier work] was a photon self-energy calculation, rather than a graviton self-energy calculation, there was no need for ghosts. . . . They weren't invented until [Richard] Feynman pointed out the need for them in the early 1960s. Then the perturbation rules for the ghosts to all orders were obtained by me in 1966 and, in a slick, fast technique, by [Ludvig] Faddeev and [Victor] Popov in 1967." Indeed, I was with DeWitt in 1966 and 1967 at the Institute of Field Physics and I recall him explaining to me that he had found the rules for Feynman's ghosts to all orders.

In the early 1960s, Wheeler felt that the wave functional in quantum gravity should be a functional of three-geometries. He shared his theory with DeWitt, and that led to the famous Wheeler–DeWitt equation. On pages 58 and 59 DeWitt says, "It was not difficult to follow the path already blazed by [Erwin] Schrödinger and write down a corresponding wave equation. This I showed to Wheeler, as well as an inner product based on the Wronskian for the functional differential wave operator. . . . I wrote a paper on it in 1965, which didn't get published until 1967 because my Air Force grant was terminated, and the *Physical Review* in those days was holding up publication of papers whose authors couldn't pay the page charges." That held-up paper is the first of DeWitt's famous trilogy of *Physical Review* articles published in 1967, in which he took crucial steps toward a viable quantum theory of gravity and a renormalizable theory of non-abelian gauge fields.

Other gems in the book are the wonderful discussions by DeWitt and Wheeler about Hugh Everett III and his "relative state" or "many-worlds" interpretation of quantum mechanics (pages 91–100); an important biographical memoir (pages 123–131) by Steven Weinberg that he prepared in 2008 for the National Academy of Sciences; and an excellent introductory letter from DeWitt to his grandson, Ben, partly to explain why he chose physics (pages 1–4). DeWitt-Morette took great care in producing a well-documented and well-rounded memoir covering the many aspects of her husband's outstanding character and achievements. The only significant lacuna I noticed is that the book lacks an index of important terms.

I heartily recommend *The Pursuit of Quantum Gravity*. Beyond the physics, it delivers a uniquely personal record of what made DeWitt tick.

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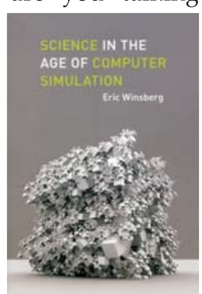
Science in the Age of Computer Simulation

Eric Winsberg
University of Chicago Press, Chicago, 2010. $24.00 paper (168 pp.). ISBN 978-0-226-90204-3

About 20 years ago, while I was taking a midday stroll with colleagues, my mind wandered to a "large" molecular dynamics simulation I was working on. (That simulation could easily run on my laptop today.) After making some progress on a couple of problems that had been troubling me, I attempted to reenter my companions' conversation by uttering, "But why should the iteration $x\,(i+1) = (a^*x\,(i) + b) \bmod p$ have anything to do with the physics of aggregate formation?" My evident non sequitur was greeted with strange looks and "Huh? What are you talking about?" The publication of Eric Winsberg's *Science in the Age of Computer Simulation* is too late to rescue that old conversation, but its existence will help to validate interest in philosophical questions



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Page 51

about computational simulation.

Winsberg adopts the methods of philosophy of science to pose questions about how computational simulations relate to physical reality. His goal is not to answer all such questions but rather to frame some of them and suggest paths for investigation. He does not try to explain why, for example, the generation of random numbers can tell us something about particulate aggregation; his intent is to locate the question on the landscape of philosophical inquiry.

Philosophical investigation of how mathematics relates to physical reality has had a long history. At first glance, computer simulations may seem to consist merely of mechanical implementations of mathematical models. However, one of Winsberg's main points is that the methods and approaches used in simulation are more than just numerical evaluations of formulas implied by mathematical analysis of a theory. Here I wish he had said something about the formal meaning of "implications" of a mathematical formulation. The claim that statement A implies statement B does not mean that B is somehow contained in A. In fact, it means that A is contained in B. Therefore, mathematical deduction locates a theory in the universe of mathematical truths, but it does not reveal the theory's content.

In contrast, computational simulation produces knowledge different from that obtainable via deductions from theory; mathematical theory guides but does not determine how numerical models are constructed. Computational formulations are often amalgams of several theories, and they include various manifestly unphysical tricks—for example, adding artificial viscosity. Such techniques, however, generate epistemological questions about the relation between results of a simulation and the physical reality.

The distinction between facts obtained via deduction and those obtained via computation is treated well in Winsberg's book. Chapter 4 discusses the difference between real and computational experiments. A particularly nice example given is the use of physical experiments as a kind of analogue computation—for example, using Bose–Einstein condensates to study the behavior of black holes. Chapter 5 discusses so-called multiscale computations, which rely on unphysical computational tricks to meld two or more incompatible theories, such as molecular dynamics and computational fluid dynamics (CFD).

Parts of the book seem to indicate a lack in the author's background in applied mathematics and computational science. One example is the discussion of "exact" solutions of a differential equation. Winsberg appears to believe that numerically evaluating the closed-form solutions to the equation provides the best results. However, it's well known that for some functions, including the Airy functions and the Hankel functions, approximating the differential equation is more numerically precise than evaluating the closed-form function directly. In general, closed-form solutions won't give more insight than will the differential equation itself. In a similar vein, the author appears to expect too much from CFD. The reader may be led to believe that computational tricks are introduced because the partial differential equations cannot be indefinitely discretized. But, of course, CFD is itself an approximation. The Navier–Stokes equations are a versatile and powerful method for modeling fluids; but fluids are, in reality, ensembles of particles.

In spite of those quibbles, *Science in the Age of Computer Simulation* is an interesting and valuable book. I hope that it will stimulate more discussion and investigation of philosophical questions engendered by the enormous role that computational simulation plays in science.

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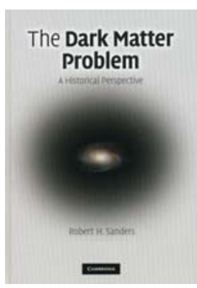
The Dark Matter Problem

A Historical Perspective

Robert H. Sanders
Cambridge U. Press, New York, 2010. $60.00 (205 pp.).
ISBN 978-0-521-11301-4

"The prevailing view of the Universe now is radically different than it was 40 years ago when I began my career as a professional astronomer," says Robert Sanders in *The Dark Matter Problem: A Historical Perspective*. In this readable and enjoyable book, Sanders takes us through the historical development of the theory of dark matter, including attempts at its direct detection, and up to the present state of affairs in astronomy, cosmology, and particle physics. And he does so with a sympathetic nod toward an unpopular competing theory.



I found the first half historically informative. It was fascinating to learn that the instability of rotationally supported disks of spiral galaxies was one of the earliest pieces of evidence for dark matter. The author deftly discusses the post–World War II emergence of radio astronomy and weaves that story into the history of spiral galaxy rotation-curve observations. He also carefully presents the roles played by those involved in the discovery process. For example, the contributions of radio astronomers Morton Roberts, Albert Bosma, and others appear alongside those of Vera Rubin, whose name is most strongly associated with the optical observations of rotation curves in the 1970s.

Several chapters in the second half of the book contain an overview of early-universe physics, cosmology, and particle physics. Those chapters are terse and technical, providing neither explanations nor equations. They belong to a category of writing that won't satisfy any audience. A reader already familiar with the topics they discuss will not learn much, and I doubt a nonspecialist will either. Some topics, it seems, are resistant to intermediate-level expositions. Sanders also includes a discussion of dark energy, which is generally viewed as a separate problem. I found it unnecessary and a little distracting.

In an idiosyncratic twist, the book offers a detailed treatment of dark matter versus modified Newtonian dynamics, or MOND, an alternative hypothesis to explain galaxy rotation curves. A chapter is devoted to MOND, and references to MOND are ubiquitous throughout the book. The author presents many arguments for and against both dark matter and MOND, with varying degrees of emphasis. In his thorough coverage of galaxy rotation curves, Sanders emphasizes that dark matter has yet to explain their small-scale features, the "conspiracy" of maximum disks, or the slope of the Tully–Fisher relation, while MOND, apparently, fares well in addressing those observations.

But MOND's weak spots—explaining the mass content of clusters and the observations of the colliding clusters of the Bullet and other systems where mass and light are separated on the sky—are presented as problematic, although potentially explainable. Sanders also notes that various, sometimes unrelated observations can be explained by dark matter. To most cosmologists, that is a powerful and persuasive argument for