The History and Practice of Ancient Astronomy

James Evans, and Alexander Jones

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BOOK REVIEWS

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Quantum Chance and Nonlocality: Probability and Nonlocality in the Interpretations of Quantum Mechanics. W. Michael Dickson. 244 pp. Cambridge U.P., New York, 1998. Price: $69.95 ISBN 0-521-58127-3. (GianCarlo Ghirardi, Reviewer.)

This book is devoted to the analysis of the foundational problems of quantum mechanics, and discusses in a quite exhaustive way the difficulties encountered by the standard formulation of the theory, as well as almost all serious proposals which have been put forward to overcome them. A very nice feature of the book is the emphasis on precise perspectives which arise from the most problematic features of the theory: indeterminacy and nonlocality.

A remark about the level of the book: Even though the author declares that he has tried to make the book as accessible as possible, given the nature of the topic, it is by no means easy reading. The systematic use of probability theory, the statistical operator formalism in both the Schrödinger and Heisenberg pictures, classical and quantum logic, stochastic differential equations, etc., require some facility in handling rather refined tools of modern science. But this is to a large extent unavoidable if one wants to give a detailed account of rather subtle aspects of the formalism and its interpretation. The author makes a highly meritorious effort to enrich the discussion of subtle formal points with simple examples cleverly chosen from common experience.

The first part is appropriately devoted to quantum chance, and deals mainly with difficulties in nonrelativistic quantum mechanics. This is the most interesting part of the book. The probabilistic perspective provides for a systematic identification of the key problems in the ''orthodox'' theory, such as the measurement problem and the nature of quantum probabilities. This part will provide a stimulating experience for students and others interested in the foundational problems of quantum theory.

Chapter 2 is, in my opinion, one of the best in the book. It makes a persuasive case that the orthodox interpretation is unsatisfactory, and it identifies in a quite convincing and lucid way the limitations of the projection postulate. Section 2.3 offers an appropriate and accessible exposition of the so-called ''dynamical reduction program'' including the CSL (continuous spontaneous localization) theory, and succeeds in making crystal clear some of the most subtle aspects of the formalism, such as the ''tails problem'' and the one involving conscious perception by humans or by science fiction creatures such as David Albert's John.

Similarly Chapter 3 presents very lucidly the many worlds and many minds interpretations, and it properly stresses that these interpretations cannot claim to account for the probabilistic aspects of quantum theory—a critical point that is rarely made so neatly. The analysis of ''no collapse'' theories, such as the ''consistent histories'' picture, even though unavoidably limited, illuminates some crucial points. The modal interpretations are presented in perhaps too technical terms, but their analysis certainly makes for stimulating reading. While I consider acceptable the presentation of Bohmian mechanics, I think that the problem of typicality (i.e., of the probabilities of the initial conditions) is not discussed with sufficient detail to allow the reader to grasp its essence.

The second part of the book tackles the subject of nonlocality. While the general presentation of the problem is entirely satisfactory, when the author goes on to analyze the various proposed interpretations, the treatment is either vague (as the author himself admits in the last sentence of the book, and is to some extent, given the difficulty and the still open nature of the matter, unavoidable) or even seriously misleading. The paradigmatic example of this last situation is represented by the analysis of relativistic CSL theory. The author has failed in understanding its basic features and, consequently, gives an incorrect assessment of its implications. He has assumed that the figures and the conclusions which have been presented by some of the proponents of the theory (P. Pearle, R. Grassi, and myself) illustrating ambiguities concerning the properties of an entangled microsystem when its partner is subjected (at space-like separation) to a measurement, apply also to the case in which one is dealing with two macroscopic apparatuses. On page 185 the author states: ''figure 9.2 depicts the region of space-time in which the apparatus for α has no 'objective' properties—call this region 'the proscribed region' for that apparatus.'' Accordingly, in his opinion, the theory meets serious difficulties and, in particular, the move that his proponents have made to restore objectivity ''is not very satisfactory and certainly *ad hoc*.'' Figure 9.3 shows how this ambiguity can be extended to other space-time regions, always with reference to macroscopic systems. These remarks show that the author has missed completely the way in which relativistic CSL works. The ambiguities about properties concern microsystems exclusively: When one has two apparatuses, each of them, at any point of its world line, is either in the ready state or in a state in which ''its pointer points to a precise position''—apart from a split second (the reduction time), to use John Bell's words. Thus Section 9.2 is seriously misleading, and I think it is my duty to warn the reader to refer to the original papers to understand relativistic CSL.

Finally, one minor and quite personal remark. As I have stated, the presentation of nonrelativistic CSL theory in Chapter 2 is absolutely correct and illuminating. But I cannot help noticing that no clear and explicit mention is made of the role played by the so-called GRW (Ghirardi, Rimini, Weber) theory in the development of CSL theory, nor of the fact that (as has been proved explicitly by Pearle, Rimini, and myself) the GRW and CSL theories are essentially the same from a conceptual point of view (both of them add stochastic and nonlinear corrections to the Schrödinger equation) and also from the point of view of their physical implications. The GRW paper is cited only in footnote 5 to Chapter 2, together with many other papers which have certainly not played an analogous role in the program. I am perfectly sure that P. Pearle himself (not to mention the late J. S. Bell), and all those who have been interested in the dynamical reduction program, would agree in considering rather misleading the role that the book seems to attach (or rather fails to attach) to the original GRW paper. It is natural, I suppose, that an American author would tend to emphasize the American contribution to the subject, but understandable, too, I hope, that a European reviewer would seek to redress the balance.

I would like to conclude by stating once more that the work of W. M. Dickson represents very interesting reading for anyone concerned with the foundational problems of our best theory. I warmly recommend it to students and scholars.

GianCarlo Ghirardi is Director of the Department of Theoretical Physics at the University of Trieste and member of the Academic Board of the International Centre for Theoretical Physics in Trieste. He is coauthor of the book Symmetry Principles in Quantum Physics *published by Marcel Dekker (NY, 1970). Since 1976 he has been involved in foundational problems of quantum mechanics, and, with Rimini and Weber, proposed a dynamical reduction model which, like Bohm's theory and the Decoherent Histories approach, is an example of quantum mechanics without observers (see S. Goldstein, Physics Today, issues 3 and 4 of 1998).*

The History and Practice of Ancient Astronomy. James Evans. 480 pp. Oxford U.P., New York, 1998. Price: $65.00 ISBN 0-19-509539-1. (Alexander Jones, Reviewer.)

When one considers how much good work has been done on the history of ancient Mesopotamian and Greek astronomy since 1900, it is surprising how few books intended for the nonspecialist have been written on the subject. Still rarer are the books that one would be happy putting in the hands of a beginner. The most successful recent efforts are either brief surveys, such as the chapters in *Astronomy Before the Telescope*, edited by C. B. F. Walker, or treatments of special topics. James Evans's book is in a different category, being a large-scale detailed survey of practically all facets of Mesopotamian and Greco–Roman astronomy, both mathematical and nonmathematical, from the second millennium B.C. to the second century A.D. There are also forward glances to medieval astronomy, Copernicus, Tycho, and Kepler.

That this book has the desired attributes of an introductory presentation, that is, that it is clearly written, accurate, up-to-date, and balanced, calls for praise but little elaboration. What does invite comment is the ''practice'' in its title. Evans's conception of astronomy is not just an intellectual pastime but very much an activity, and one that the reader is continually invited to share. One learns how to convert dates between ancient calendars, how to compile a Greek-style weather calendar, how to make a sundial, how to use an astrolabe, how to calculate planetary positions in both the Babylonian and Ptolemy's manner. If the inclusion of such exercises tends to make the book resemble an American university textbook (an impression heightened by the layout of the pages), it is nevertheless an admirable feature. Trying these things out for oneself is often the most effective way of understanding the principles, and one also gains a much more accurate general impression of what this astronomy was about than from conventional presentations that focus almost exclusively on the evolution of celestial mechanics.

I have only two broad reservations about Evans's selection and organization of his material. He has decided to pass over ancient lunar theory almost entirely, on account of its relative complexity and the additional space it would demand. These are understandable reasons, but the moon cannot be left out of ancient astronomy without considerable cost. Mesopotamian astronomy, in particular, was from the beginning much more deeply concerned with the phenomena of the moon than with the planets, and the Babylonian mathematical models for the planets give few hints of the analytical brilliance of their theories of lunar visibility and eclipses. In Ptolemy's astronomy, by contrast, the treatment of the moon is not essentially different from that of the planets, so that the effect of the omission is unequal for the two traditions.

The plan of the book is by topic, and the sequence is an essentially Greek one, beginning with the celestial sphere, and progressing through calendrics, solar theory, the fixed stars, and the planets. Evans provides a brief historical outline in his first chapter, but for many readers this will not be enough of a corrective to the main text, where, for example, Babylonian arithmetical planetary theory is oddly sandwiched between Eudoxus's models of concentric spheres and Ptolemy's eccentric orabits and epicycles. The historical element of time is not conspicuous, and again the Mesopotamian tradition suffers disproportionately. The development of Mesopotamian astronomy in its own right is presented more coherently at an introductory level in B. L. van der Waerden's *Science Awakening II: The Birth of Astronomy*; but as an exposition of Greek astronomy, including its relations to Mesopotamia, Evans's book can be warmly recommended.

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Classical Electrodynamics. Julian Schwinger, Lester L. DeRaad, Jr., Kimball A. Milton, and Wu-yang Tsai. 569 pp. Perseus, Cambridge, MA, 1998. Price: $60.00 ISBN 0738200656. (Jagdish Mehra, Reviewer.)

This is a remarkable document. The late Julian Schwinger was not only one of the leading theoretical physicists of the century, but a superb teacher. His contributions to quantum electrodynamics, to quantum field theory, and to quantum mechanics are well known. Perhaps not so familiar are his insights in classical physics, particularly in classical electrodynamics. Here his fame is less than it deserves to be, because he hesitated to publish much of what he learned. He was effectively the leader of the theoretical waveguide group at the MIT Radiation Laboratory during World War II, where he developed powerful variational methods for solving Maxwell's equations in complicated geometries, making essential use of Green's function techniques. Although he presented much of this work to his co-workers in seminars during and immediately after the war, only a small fragment was published, in collaboration with David Saxon.[1] Some of his techniques were published in a series of papers with Harold Levine on classical diffraction problems. But the most significant publications growing out of his wartime work were on the subject of synchrotron radiation.[2] His only competition on this subject was the Russian school.[3]

Immediately after the war, in his first few terms as Professor at Harvard, Schwinger taught courses on waveguides and classical electromagnetic theory, but he soon had no time for that, due to the pressure of his work on *quantum* electrodynamics. The Green's function and variational techniques, as well as insights into the nature of electromagnetic mass, developed in the classical context, were to prove invaluable in his development of renormalization theory, and the covariant formulation of quantum field theory. But he covered his classical tracks. Apparently it was only 30 years later, well after his move to UCLA, that he taught classical electrodynamics again. He had at that time a talented group of postdoctoral associates, whom he had brought with him from Harvard. Of the three, it was surely Kimball A. Milton who suggested that Schwinger's superb and unique lectures be turned into a book. Schwinger was agreeable, so long as his young associates did the work. They prepared a typed manuscript, circulated it to several publishers, and received a signed contract from W. H. Freeman. At this point, around 1979, Schwinger paid attention, and read the typescript. Unfortunately, he felt it sounded too little like himself, and more like Milton, Tsai, and DeRaad, and so commenced rewriting. At first, that rewriting was in collaboration with the trio of coauthors, but later he decided to make it a solo effort. He taught the course a few more times, and continued rewriting until he abandoned the project, still on the subject of electrostatics, in 1984.[4] He became frustrated, he said, because of the difficulty of competing with ''Jackson.'' Thus the project lay dormant until 1995, when, just after Schwinger's death, Milton started teaching the course again at the University of Oklahoma and decided to bring out the book. The text reviewed here is the result of Milton's effort, combining the best of the original manuscript written by Milton, DeRaad, and Tsai, and the massive revisions of the first half of the book by Schwinger, as well as some later lectures of Schwinger on waveguides and partial waves.

This book is a completely self-contained treatment of the subject. As was typical of Schwinger's style and philosophy, the mathematics grows out of the physics. Maxwell's equations appear full blown by the end of the first chapter, and conservation laws appear before 30 pages are over. Macroscopic electrodynamics appears in the fourth chapter followed by simple classical models for constitutive relations, both electric and magnetic. The problems of defining macroscopic energy and momentum are briefly treated in Chapter 7. A powerful variational formulation of electrodynamics is the subject of Chapter 9. Special relativity is discussed, based on the electrodynamic context, in Chapter 10, although the covariant notation is relegated to problems at the end of the chapter. Finally, a quarter of the way through the book electrostatics comes into focus.

Typically, electrostatics is treated with a variational principle, and through the use of Green's functions. In the next several chapters, Green's functions are worked out for several geometries, first empty space, then with plane and cylindrical boundaries between dielectrics and conductors. By analyzing such problems in different ways, the properties of Bessel functions, for instance, emerge from the physics. In Chapter 20, spherical harmonics appear, based on solutions of Laplace's equation characterized by a null vector—a powerful technique reminiscent of Schwinger's famous work on angular momentum theory in quantum mechanics.[5] This leads to a beautiful treatment of electric multipoles. Standard problems of dielectric and conducting spheres are treated with uncommon elegance. A general theory of capacitance is presented—how else?—in terms of Green's functions. The section on electrostatics concludes with a wonderful chapter on Schwinger's famous iteration-variation method in the context of conducting cavities, a precursor of things to come.

Magnetostatics receives rather short shrift, presumably because of the pressure of time in the courses upon which this book is based. It is a pity that Schwinger did not find time to elaborate more on this subject; yet, what is here, in four short chapters, is certainly adequate for a course on electrodynamics. The sign adopted for the magnetostatic energy may be cause for some perplexity, but it reflects the use of the current distribution as a prescribed source, rather than as a dynamical variable, and it results in simpler calculations of the forces between currents. The problems in these chapters, as elsewhere in the book, are crucial for further elaborating the subject, and fleshing out the details.

A little over halfway through the book, the subject becomes radiation. Beginning with a relatively standard derivation of the Liénard–Wiechert potentials, the authors obtain compact formulas for the power radiated in terms of the current distributions. After a brief look at antennas, they obtain an expression for the spectral distribution in terms of the Fourier transform of the current. This can be further recast into an approximately defined macroscopic power spectrum—not an oxymoron. Applications are made to Cerenkov radiation and to constant acceleration, a subject only treated relativistically in the problems; here there arises a posthumous confrontation with Pauli, who had claimed, apparently incorrectly, that hyperbolic motion does not give rise to radiation.[6] The centerpiece of the radiation portion of the book is the three chapters on synchrotron radiation. This, together with important supplements in the problems, is destined to become a classic, yet quite accessible, treatment of what is still a bit of a difficult subject. No book on electrodynamics can avoid Snell's law; here reflection and refraction are presented elegantly in terms of TE and TM modes, although Schwinger used his own notation, *H* and *E* modes, respectively. The formalism is generalized to waveguides, and a connection is made with the variation-iteration method discussed in statics. Scattering, after an initial elementary treatment, is cast in the same formalism. There are two lovely chapters on diffraction, the second of which gives Schwinger's version of the exact solution found by Sommerfeld for diffraction by a straight edge.[7] A chapter entitled ''General Scattering'' is noteworthy for its introduction of Debye potentials and vector spherical harmonics, albeit in the problems.

Two final chapters grew out of lectures Schwinger gave in connection with his lifelong interest in magnetic monopoles. The question was how the magnetic charge interacts with bulk matter, and the answer, in terms of energy loss, depends on dispersion. General dispersion relations for the electrical susceptibility are derived and applied to give models for that energy loss. Quite apart from this speculative application, the dispersion relations for the dielectric function and its inverse are most valuable.

So, how do I judge this book? It clearly bears marks of its origin: lectures by a master of twentieth century physics; and, it is clear to me that much of the flavor of those exciting lectures is captured here. Because this book is based on the notes of Schwinger's lectures, it is less encyclopedic than many textbooks tend to be, which is perhaps a virtue; while there is more here than can reasonably be covered in a typical one-year graduate course, the amount of material is not overwhelming. And the subject is presented not as a cold, dead subject, bequeathed to us by our nineteenth century ancestors, but as a vibrant subject of research, to which the student can contribute.

It is impossible to review a book on classical electrodynamics without mentioning the overwhelming presence of the Jackson book, now in its third edition.[8] Jackson's book has many virtues, but, in my view, they pale in comparison with those of the Schwinger volume. First, and rather trivially, Jackson has now caved in to commercial pressure to conform to the engineering predilection for SI units (but only in the first part of the book). This is ludicrous for a book on theoretical physics: How can the electric and magnetic fields have different units, when they are but different components of the field strength tensor? More important is that Jackson begins by presenting the mathematics of boundary value problems as a subject of applied mathematics, and then introduces electrostatics; while Schwinger *et al.* integrate the subjects, making the mathematics of special functions follow as a consequence of different ways of viewing physical phenomena. Again and again the Schwinger treatment seems to hit the nail squarely on the head, while Jackson's book creates confusion. As one example, consider the classic problem of the force on a dielectric in a capacitor. Instead of considering the work done by the battery and the energy stored in the capacitor, here the result emerges transparently from the variational treatment. Pedagogically, there is no comparison; Schwinger wins hands down.[9]

Is this conclusion surprising? Hardly, for Jackson was (unofficially) one of Schwinger's many illustrious students, and he learned much of what appears in his textbook from the master. It is unfortunate, and a reflection of Schwinger's impossibly high standards, that it is only now that some of his marvelous insights into classical field theory are being presented to the world. If you are a physicist, mathematician, or engineer, buy this book. If you are teaching a graduate course on electrodynamics, consider adopting this book very seriously, and use it as a supplement if you find it too hard to adapt to Schwinger's style and demanding standards. And if you are a librarian, consider this book as an essential resource. Physics does not get any better than this. I recommend this book wholeheartedly to teacher and student alike; this is the best book on classical electrodynamics produced at the end of the twentieth century, and it will continue to fulfill the needs of budding scientists of the twenty-first century.

[1] J. Schwinger and D. Saxon, *Discontinuities in Waveguides* (Gordon and Breach, New York, 1968).

[2] J. Schwinger, Phys. Rev. **75**, 1912 (1949). An earlier version, circulated in hectograph form, was quite different: ''On Radiation by Electrons in a Betatron,'' written in 1945, but recently transcribed and circulated as preprint by Michael Furman: LBNL-39088, 1996.

[3] For a Russian history of the theory of synchrotron radiation, see A. Sokolov and I. M. Ternov, *Synchrotron Radiation* (Akademie-Verlag, Berlin; Pergamon, Oxford, 1968).

[4] The manuscripts of this effort from various stages may be found in the Julian Schwinger Papers (Collection 371), Department of Special Collections, University Research Library, University of California, Los Angeles.

[5] J. Schwinger, ''On Angular Momentum,'' unpublished US AEC Report No. NYO-3071, published in L. C. Biedenharn and H. van Dam, *Quantum Theory of Angular Momentum* (Academic, New York, 1965), p. 229.

[6] W. Pauli, *Theory of Relativity* (Pergamon, Oxford, 1958), p. 93.

[7] A. Sommerfeld, Math. Ann. **47**, 317 (1895).

[8] J. D. Jackson, *Classical Electrodynamics* (Wiley, New York, 1998), 3rd ed.

[9] There are two other excellent textbooks on the subject, those of Panofsky and Phillips, and of Stratton. (I leave aside the stimulating Landau and Lifshitz volume, which cannot really be used as a text, at least in the American curriculum.) In many ways I have always felt that those books were superior to Jackson's, and they remain profoundly worthy contenders.

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BOOKS RECEIVED

High Field Superconducting Magnets. Fred M. Ašner. 235 pp. Oxford U.P., New York, 1999. Price: $100.00 ISBN 0-19-851764-5.

Integrable Systems: Twistors, Loop Groups, and Riemann Surfaces. N. J. Hitchin *et al.* 136 pp. Oxford U.P., New York, 1999. Price: $45.00 ISBN 0-19-850421-7.

An Introduction to Mathematical Physiology and Biology, 2nd ed. J. Mazumdar. 226 pp. Cambridge U.P., New York, 1989, 1999. Price: $74.95 (cloth) ISBN 0-521-64110-1; $29.95 (paper) ISBN 0-521-64675-8.

Light Scattering by Nonspherical Particles: Theory, Measurements, and Applications. Edited by Michael I. Mishchenko *et al.* 690 pp. Academic, San Diego, CA, 2000. Price not given ISBN 0-12-498660-9.

Looking Within: How X-Ray, CT, MRI, Ultrasound, and Other Medical Images Are Created and How They Help Physicians Save Lives. Anthony Brinton Wolbarst. 206 pp. University of California Press, Berkeley, CA, 1999. Price not given (paper) ISBN 0-520-21182-0.

Measurement, Instrumentation and Experiment Design in Physics and Engineering. Michael Sayer and Abhai Mansingh. 368 pp. Prentice–Hall of India, New Delhi, India, 2000. Price: Canada $19.50 (paper) ISBN 81-203-1269-4.

Models as Mediators: Perspectives on Natural and Social Science. Edited by Mary S. Morgan and Margaret Morrison. 401 pp. Cambridge U.P., New York, 1999. Price: $64.95 (cloth) ISBN 0-521-65097-6; $24.95 (paper) ISBN 0-521-65571-4.

New Foundations for Classical Mechanics, 2nd ed. David Hestenes. 703 pp. Kluwer Academic, Norwell, MA, 1986, 1999. Price: $268.00 ISBN 0-7923-5302-1.

Nonclassical Physics: Beyond Newton's View. Randy Harris. 608 pp. Addison–Wesley, Menlo Park, CA, 1999. Price not given ISBN 0-201-83436-7.

Nucleon-Hadron Many Body Systems: From Hadron-Meson to Quark-Lepton Nuclear Physics. Edited by Hiroyasu Ejiri and Hiroshi Toki. 344 pp. Oxford U.P., New York, 1999. Price: $140.00 ISBN 0-19-851900-1.

Principles of Stable Isotope Distribution. Robert E. Criss. 254 pp. Oxford U.P., New York, 1999. Price: $65.00 ISBN 0-19-511775-1.