

Rotation and Accretion Powered Pulsars

Pranab Ghosh

**World Scientific, Hackensack, NJ,
2007. \$182.00 (772 pp.).
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The existence of neutron stars was confirmed with the discovery of radio pulsars in August 1967. Researchers became generally optimistic that it would not be too difficult to explore and understand the physical properties of a rotating, magnetized compact star with a radius of approximately 10 km. However, more than 40 years later, scientists studying neutron stars have lost that illusion as they have realized how complex neutron stars are and how challenging it is to understand their physical properties.

Neutron stars form in supernova explosions and by accretion-induced collapses of white dwarfs. At the time of their discovery, and for many years thereafter, it was generally accepted that neutron stars could only be observed as pulsars. According to the source of energy, they were split into two classes: pulsars

powered by rotation and those powered by accretion. Today, the neutron-star world is much more intricate than it was four decades ago. In addition to the accretion-powered pulsars, which are predominantly bright x-ray sources, and the rotation-powered pulsars, which are observed throughout the electromagnetic spectrum, astrophysicists have identified x-ray dim isolated neutron stars (XDINs), radio-quiet neutron stars, compact central objects (CCOs) in supernova remnants, rotating radio transients (RRATs), soft gamma-ray repeaters, and anomalous x-ray pulsars.

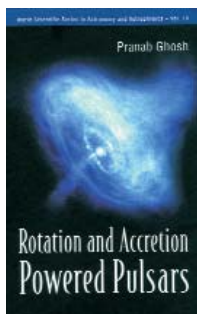
Because most of the observational facts and theoretical questions regarding rotation- and accretion-powered pulsars are quite different from one another, the two classes of pulsars are usually treated separately. The link between them is millisecond pulsars, which are believed to be old neutron stars that have spun up to millisecond rotation periods in a past accretion phase. *Rotation and Accretion Powered Pulsars* by Pranab Ghosh, a faculty

member in the department of astronomy and astrophysics at the Tata Institute of Fundamental Research in India, is the first effort I know of that summarizes in a single book the physics and observational facts of both classes. Its 750-plus pages include discussions of the discovery of pulsars; the physics of degenerated stars and dense matter; the origin and evolution of neutron stars; the properties of rotation- and accretion-powered pulsars and their emission mechanisms; and spin and magnetic-field evolution. The book also contains a chapter on quark stars and an appendix that provides brief sections on stellar classification, color index, astronomical coordinate systems, time keeping, and other astronomical preliminaries.

Having a single reference for both classes of pulsars may provide some comfort for researchers in the field, but Ghosh's merging of so many topics into a single book is not without its problems. Most important is the limitation of space. There are excellent books on the market, each focusing exclusively on topics like the physics of dense matter, theoretical and observational aspects of rotation-powered pulsars, and accretion-powered pulsars. But in his condensed book, Ghosh has to be brief in each subject he addresses. As a consequence, he gives only a narrow view of many of the covered topics, and readers are pointed to secondary literature and are left to deal with step-by-step derivations of formulas on their own. Other practical disadvantages are that the book is expensive and heavy. Its weight makes it somewhat uncomfortable to work with and thus disqualifies it as a useful reference one can carry around; its price makes it invalid as an affordable text for most students.

Apart from those objections, the compact and often complicated way in which the author describes subjects further disqualifies the book as a student textbook. I offer two examples: First, although Ghosh takes more than a page to describe what r-modes are, he does not provide enough background and descriptive visualization; thus most undergraduates may still find them difficult to imagine. Second, while describing polarization and the rotating-vector model, Ghosh takes almost a page to give a complicated description of the different angles and geometries, when a simple plot that shows the viewing geometry and angles would have made everything clearer.

According to the information on the book's back cover, the "unifying thread



of the evolutionary link between rotation- and accretion-powered pulsars is a milestone of modern astrophysics.” That description appears to be an overstatement: In my opinion, there is no milestone, and I seriously doubt that such a claim is solid justification for acquiring Ghosh’s book. It is further advertised that the book starts with simple, basic physical concepts and builds up to the point where the latest and most exciting developments become accessible to readers. That is simply incorrect. In addition, important recent developments concerning, for example, cooling neutron stars, gamma-ray pulsars, XDINs, CCOs, and RRATs have been omitted.

Despite its flaws, *Rotation and Accretion Powered Pulsars* may be useful as an introductory text, but mostly in the sense that it provides a starting point for interested readers. Thus Ghosh’s text should be in every university library.

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Functional Integration

Action and Symmetries

**Pierre Cartier and
Cécile DeWitt-Morette**
Cambridge U. Press, New York,
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Since its inception in Richard Feynman’s 1942 doctoral thesis, the path integral has been a physicist’s dream and a mathematician’s nightmare. To a physicist, the path integral provides a powerful and intuitive way to understand quantum mechanics, building on the simple idea that quantum physics is fundamentally a theory of superposi-

tion and interference of probability amplitudes. The “sum over histories” offers a framework for tackling problems ranging from Feynman diagrams to lattice chromodynamics, from quantum cosmology to superfluid vortices to stock-option pricing. To a mathematician, the path integral is at best an ill-defined formal expression. It is some sort of vaguely integral-like object involving a “sum” over a badly specified collection of functions, having an undefined measure, and whose value is apparently determined by a group of unclear and perhaps incompatible limits that may or may not yield finite answers.

Pierre Cartier and Cécile DeWitt-Morette’s *Functional Integration: Action and Symmetries* is both a survey of selected path-integral methods and a valiant effort to put those methods on a sound mathematical footing. DeWitt-Morette, a mathematical physicist and professor emerita at the University of Texas at Austin, has spent much of her career thinking about how to make sense of the path integral. Her first paper on the subject dates back to 1951. Cartier, a member of the Bourbaki group—Nicolas Bourbaki was the pseudonym for the famous group of French mathematicians—is a researcher at the Institute of Advanced Scientific Studies in France. He adds broad expertise and a further degree of mathematical rigor to the text.

The first 10 chapters focus on Gaussian path integrals, for which the action is either quadratic in the fundamental variables or contains higher-order terms that can be treated perturbatively. Most of the material is not new, although the authors are careful to define their domain of integration far more precisely than other authors, and they

show that their constructions are valid without requiring a Wick rotation to imaginary time. The chapters contain interesting discussions of curved spaces, noncommuting variables, and approximation methods.

Chapter 11 describes an elegant extension of differential geometry to infinite-dimensional function spaces, and it is worth reading in its own right. For readers interested in the mathematical foundations, chapters 12–14 are the real meat of the book, where the authors construct mathematically rigorous path integrals for the Klein–Gordon, Dirac, and time-independent Schrödinger equations. Although the final results are those that a physicist would expect, the derivations are now at a level a mathematician might accept. Again, no Wick rotation is needed; path integrals are defined in terms of real time and a Lorentzian metric, a task many thought impossible to pull off.

The next four chapters, 15–18, discuss various topics in quantum field theory, including a Lorentzian approach to the renormalization group and a Lie algebraic approach to Feynman diagram combinatorics. The book’s concluding chapter, 19, contains a list of “projects,” many of which could form the bases of good PhD dissertations, and is followed by extensive appendixes.

Scattered throughout the book are many little gems of insight. Cartier and DeWitt-Morette refute the folk theorem that the propagator for the anharmonic oscillator (the harmonic oscillator with an additional λx^4 term) is singular at $\lambda = 0$. They give a beautiful summary of the many inequivalent perturbative expansions available in different regimes. They discuss the role of the topology of the space of paths, showing how the distinction between bosons and fermions

