The Physics of Black Holes

Black Holes. The Membrane Paradigm. KIP S. THORNE, RICHARD H. PRICE, and DOUGLAS A. MACDONALD, Eds. Yale University Press, New Haven, CT, 1986. xiv, 367 pp., illus. $40; paper, $14.95.

Until now, essentially all books devoted to the subject of black holes have been either popularizations or sophisticated treatises dealing mainly with their mathematical structure. *Black Holes: The Membrane Paradigm* is undoubtedly the first major volume to treat black holes from the point of view of "applied physics." Its main aim is to provide a practical formalism for describing phenomena around black holes that can be used by non-experts in general relativity. It proceeds by recasting the equations describing these phenomena—such as the structure of electromagnetic fields produced by plasmas around a black hole or the evolution of a black hole perturbed by an external tidal gravitational field—in a form closely resembling the equations describing similar phenomena in ordinary three-dimensional space. A key step in this procedure is to endow the horizon of the black hole with attributes such as surface charge, electrical conductivity, and temperature. (Actually, for reasons having to do with the fact that the authors use spatial surfaces that intersect the horizon at the bifurcation two-sphere [where the "time translation" isometries vanish], they choose to work with a timelike surface displaced slightly outward from the horizon—the so-called "stretched horizon.") In this manner, the black hole horizon is treated as though it were an ordinary physical surface. This accounts for the subtitle of the book, "The Membrane Paradigm."

The book is actually a collection of eight separate chapters by different authors. Nevertheless, it has the unity and coherence of a singly authored volume. Undoubtedly, this is at least partly explained by the fact that Thorne is not only an editor of the volume but a coauthor of every chapter. Numerous interesting model problems are worked out throughout the book, and the discussion is uniformly clear, with many well-labeled diagrams and figures. There is, however, little discussion of purely theoretical issues such as why the membrane paradigm exists, that is, why it should be possible to rewrite equations so that the horizon can be treated as an ordinary surface.

As already indicated above, the main intended readership of the book is astrophysicists and other physicists who are not expert in general relativity. However, unless such a non-expert reader wishes only to obtain some "cookbook" prescriptions for solving certain problems, it is necessary that his or her knowledge of general relativity be at least equivalent to what would be obtained from an introductory graduate course at the level of the Misner, Thorne, and Wheeler textbook *Gravitation*. Indeed, that book is cited frequently throughout *Black Holes* for explanations of such things as the sources of the various equations, and the non-expert reader undoubtedly would need to keep a copy of it handy in order to follow the discussion.

I believe that the book is quite successful in its treatment of electrodynamic phenomena around black holes in the first four chapters. The membrane paradigm formalism is sufficiently similar to standard electrodynamics that all readers should be able to gain understanding and intuition about these processes. In particular, the Blandford-Znajek process for extracting rotational energy from a black hole surrounded by a magnetized plasma is well explained in this formalism. The experts in general relativity will also learn much from these chapters.

Although the next four chapters, on gravitational interactions involving black holes, are as well written as the preceding four, I believe the book is considerably less successful here. This is largely because the intuition of the non-expert reader will be much poorer for these phenomena. In addition, much more detailed and technical results are employed in the analysis; the references for explanations or derivations of equations no longer are to *Gravitation* but now are mainly to the current research literature. Thus, in particular, I find it difficult to picture a non-expert reader making it through chapter 6 unscathed. On the other hand, the expert readers probably would want to make their own favorite gauge choices and probably would be more comfortable thinking about null geodesics than the behavior of a (fictitious) "fiducion fluid." Nevertheless, these chapters will at the very least serve as a useful guide to the literature for non-expert readers who are trying to become experts, and the solutions to the numerous model problems will provide a useful reference for the expert readers.

The final chapter of the book concerns black hole thermodynamics, specifically the thermal properties of the region around the black hole (its "atmosphere") as measured by stationary (as opposed to freely falling) observers. The entropy contributed by layers of this "atmosphere" is calculated and used to justify the validity of the generalized second law of thermodynamics and the idea that the entropy of a black hole corresponds to the logarithm of the number of its possible "internal states." Both experts and non-experts should find the points of view introduced in this chapter to be of interest.

In summary, non-experts in general relativity should find this book a very useful guide to analyzing astrophysical phenomena around black holes, although they may not have an easy time with some of the later chapters. The experts will find it a valuable reference, mainly on account of the numerous model problems that are analyzed. Undoubtedly, both will wish to own copies of the book.

ROBERT WALD
*Enrico Fermi Institute,
University of Chicago,
Chicago, IL 60637*

Group Selection Reiterated

Evolution through Group Selection. V. C. WYNNE-EDWARDS. Blackwell Scientific, Palo Alto, CA, 1986. xii, 386 pp., illus. $58; paper, $29.

Group selection may be thought of as a change in gene frequencies within a population resulting from the differential reproductive success of local subgroups of that population. The concept becomes controversial when it is postulated to cause the evolution of traits, such as sacrifice of personal reproduction, that are unfavorable in terms of individual selection. Although he was not the first to propose that group selection has shaped the social world of animals, Wynne-Edwards triggered two decades of substantive debate about the topic with his 1962 book, *Animal Dispersion in Relation to Social Behaviour*. No sooner did he make group selection an everyday expression in biology than it was denounced by a host of biologists as impossible and unnecessary as an explanation of social (or other) adaptations. The concept has undergone a steady renaissance over the past decade, having once "rivaled Lamarckianism as the most thoroughly repudiated idea in evolutionary theory" (D. S. Wilson, *Ann. Rev. Ecol. Syst.* **14**, 159 [1983]).

Wynne-Edwards's early, vigorous exposition on group selection caused evolutionary biologists to broaden and sharpen their reasoning about mechanisms of natural selection. Unfortunately, the present work is not likely to produce similar results. The author