Black holes made easy

William H. Press

Black Holes: The Membrane Paradigm. Edited by Kip S. Thorne, Richard H. Price and Douglas A. Macdonald. *Yale University Press: 1986. Pp.367. Hbk $37.50, £37.50; pbk $12.95, £9.95.*

WHERE are the black holes? Have they gone the way of steady-state cosmology and phlogiston, or are they still an essential element of contemporary astrophysical understanding?

The answer is that black holes, of about 10^8 solar masses, are alive and well and living in quasars and active galactic nuclei. This blunt statement is accepted by most researchers in the field, but it has been unexpectedly difficult to prove by any single, direct observation. Rather, the past decade has seen the continuing accumulation of data and theoretical understanding consistent with the black-hole model, and not very consistent with any other model. These advances may no longer have the ability to grab popular headlines (or stampedes of PhD students), but steady progress is punctuated by elegant new insights and syntheses. One of the most fruitful of them is the 'membrane viewpoint', developed by Kip S. Thorne and his collaborators, several of whom are contributors to this book.

The idea is this: Suppose we are willing to restrict our study to the interaction of already formed black holes with the external, astrophysical universe, putting aside for another book questions of black-hole formation and interiors. Then we want to think of the black hole not as a 'spacetime', but as an 'object', a three-dimensional approximately spherical 'thing' that behaves like any other astronomical body — accretes material, interacts with external matter and electromagnetic fields, and so forth. The surface of this object can be taken to be a timelike surface, a membrane, just outside (in a sense that can be made mathematically precise) the actual event horizon of the black-hole spacetime. The game now is to 'hide' the inside of the black hole by attributing all its properties to fictional, but precisely definable, properties of the membrane.

Physically motivated thought-experiments are conducted to investigate the properties of the membrane, its electrical conductivity for example. This can be discerned in several ways, say by calculating the membrane's absorbtion of electromagnetic radiation, or its Ohmic losses in a time-varying magnetic field, or from the details of how the electric field on the membrane becomes uniform if a charge is dropped onto (into!) one point. Amazingly, all such calculations give the same answer for the conductivity. The deep reason is that the exact, fully relativistic equations for electromagnetism in a black-hole spacetime can be cast into a form *exactly* like ordinary Maxwell's equations in the presence of a conducting body.

This general idea works not only for the hole's electrical properties, but for its mechanical and thermodynamic properties as well. The membrane has a viscosity that gives rise to dissipation whenever an orbiting object raises a tidal bulge — just like the Moon's tidal dissipation in the oceans of the Earth. The membrane has an entropy and a temperature, in terms of which the black hole and its surroundings can be understood as exactly satisfying the first and second laws of thermodynamics. Once again, the analogies are not merely suggestive, the are *exact* when the equations are properly cast. The membrane viewpoint is a powerful formalism, not only for actual calculations of black-hole behaviour, but also for intuitive and qualitative understanding of a hole's behaviour in the complex astrophysical environment at the centre of a quasar or active galactic nucleus.

Although the chapters in this book were written by nine separate authors, they have been polished to speak with a single voice: it is the voice of a careful teacher who, while unafraid of mathematical precision, is not satisfied with an equation until a clear physical interpretation of it has been conveyed. By virtue of its pedagogical excellence, the book transcends its particular (membrane) viewpoint and is, quite simply, about the best single work on black holes yet written. The illustrations are numerous and clear, and the index is superb. Above all, it is a book in which physics never takes a back seat to formalism. Backed up by Chandrasekhar's uncompromisingly technical *The Mathematical Theory of Black Holes* (Oxford University Press, 1983), it represents the current and maturing state of knowledge about these exotic — but not necessarily unintuitive — astronomical bodies. □

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Of barriers and carriers

S.R. Caplan

Principles and Models of Biological Transport. By Morton H. Friedman. *Springer-Verlag: 1986. Pp. 260. DM 165.*

BOOKS on transport, especially biological transport, are two-a-penny (figuratively speaking) and at first glance it is not easy to discern why we need yet another treatise on the topic. Can there be any reason to repeat what has only just been said with great profundity in 685 pages, but this time in less than half the space?

It seems that there may be. Brevity has its advantages, especially where wordiness is replaced by precise description in mathematical terms. Because this monograph is intended to provide an introductory course for undergraduate biomedical engineers and graduate students in biophysics, the author can afford to present most of the material as an exact science, highlighting the main concepts without becoming bogged down in a mass of experimental minutiae. In this way a remarkably wide variety of topics is covered, including thermodynamics of transport processes (both the equilibrium and nonequilibrium varieties), diffusion (free and facilitated), active transport, kinetic and other models, single-cell and epithelial phenomena, gaseous processes and much else besides. Nerve, muscle and kidney all receive due attention.

Unfortunately, several caveats must be recorded. The fact that difficulties are glossed over (and important issues ignored) is less bothersome than the author's tendency to trot out often-repeated misunderstandings. Among these is the claim that the "dephosphorylation reaction" (of ATP) "is accompanied by the release of the energy stored in the terminal phosphate bond" (p.78). This actually precedes by a few pages a prominent reference to a paper by Eisenberg and Hill, wherein the surprised reader will find this view soundly debunked. Elsewhere the condition generally known as detailed balancing is said not to hold for active transport (p.101), and the reflection coefficient is indicated to lie between zero and unity (p.119).

The sternest caveat, however, relates to the inadequate and arbitrary referencing of sources. Quoting from contemporaries without citation is a serious discourtesy, which, moreover, denies the reader access to the most relevant literature. By contrast, the gentleman cited repeatedly as "van t'Hoff" might have welcomed anonymity!

Still, this is a book that will repay study by those who keep their wits about them. □

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•In his review last week (p.218), Robert Whittle expressed the hope that Wiley would issue a "more imaginatively" priced edition of *Genetic Analysis of Animal Development*. The book will appear in paperback in May; price will be £25.40, $34.95, against £66.95, $69.95 for the hardback.