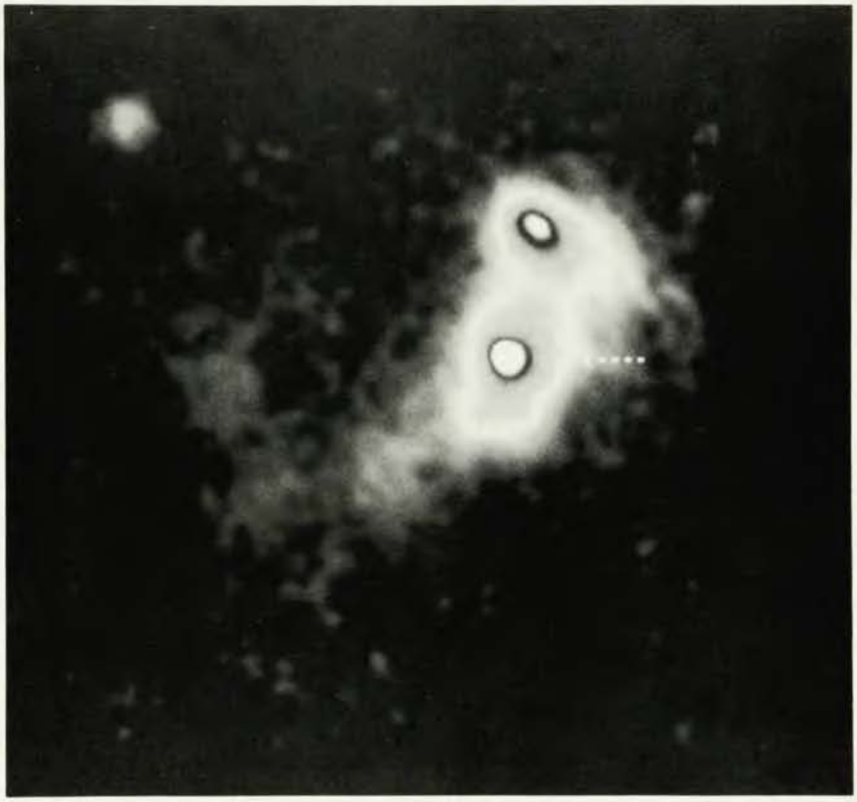
books

The collapse of burned-out stars



Supernova remnant, located in the constellation Circinus in the southern sky. The arrow indicates the location of a pulsar, the collapsed remnant of the exploded star. This x-ray photo was taken by the Einstein orbiting observatory. (Courtesy of Fred Seward and Tom Stephenson.)

Black Holes, White Dwarfs, and Neutron Stars: The Physics of Compact Objects

S. L. Shapiro, S. A. Teukolsky

645 pp. Wiley, New York, 1983. $39.95 cloth, $24.95 paper

Reviewed by Alan P. Lightman

In his three-page paper "On the Theory of Stars" published in 1932, Lev Davidovich Landau begins sensibly with the statement, "It seems reasonable to try to attack the problem of stellar structure by methods of theoretical physics," discovers with dismay that his own calculations predict the unavoidable and total collapse of burned-out stars just slightly heavier than the Sun, and retreats by suggesting that the laws of quantum mechanics must be abandoned. Quantum mechanics has not been abandoned. What has happened, instead, is the observation of some very strange collapsed stars overhead.

Normal stars like our Sun, before exhausting their nuclear fuel, balance their gravity with thermal pressure. In 1967, radio astronomers identified the first neutron star—a mass equal to that of the Sun compressed into a diameter of about twenty kilometers, supporting itself against gravitational collapse, but just barely, by neutron degeneracy pressure. Before neutron stars, the most compact stars known were the white dwarfs, a thousand times the size of neutron stars and supported by the pressure arising from electron degeneracy. In the early 1970s, optical and x-ray astronomers first identified a likely black hole, Cygnus X-1, 7000 light years from Earth. Black holes, of course, are former stars that have plunged fully into the depths of Landau's nightmare.

The physical conditions in and around these exotic objects extend far beyond anything achievable in the laboratory, or practically anywhere else. Neutron stars are believed to anchor magnetic fields of 10^{12} Gauss, to have interiors of superfluid neutron liquid and, perhaps, pion condensates and quark matter. A good equation of state at nuclear densities, still on the drawing boards, appears necessary before we can determine the maximum mass of a neutron star. Black holes are simpler inside, but they can have messy interactions with matter outside. Gas sucked into a black hole from the surface of an orbiting companion star first spirals into a turbulent disk, then heats up to as much as a billion degrees and radiates x rays before it disappears at light speed into the hole.

Notwithstanding Landau, physicists, and indeed most modern scientists, have grown accustomed to snooping into unfamiliar places. This splendid new book by Stuart Shapiro and Saul Teukolsky is a celebration of physics applied to distant territory. Assuming a solid background in undergraduate physics, but nothing else, the authors present a carefully written and systematic study of black holes, white dwarfs and neutron stars. The only comparable textbook, much less ambitious in scope and now over a decade old, is *Relativistic Astrophysics, Volume* 1, by Yakov B. Zeldovich and Ivan I. Novikov. Shapiro and Teukolsky's book spills over with intriguing physics. Topics include the cold equation of state above and below neutron drip, an introduction to general relativity, the equilibrium and stability of cold stars, supernovae and pulsars, neutrino opacities, binary x-ray sources, hydrodynamic accretion onto compact objects,

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gravitational radiation, and more. This is not, however, a special-topics book. It is a thorough exposition of the subject, weighted heavily towards theory, but with frequent comparison to observational data and brief and interesting historical sketches. The authors derive almost every major result from first principles, pursuing most topics right up to current research. Where refinements go beyond the scope of the book, up-to-date information can be found on the list of over 600 references at the end of the book. The result is a unique blend of the textbook and the research monograph, suitable for graduate students on up.

Shapiro and Teukolsky, both professors of astronomy and physics at Cornell, were just beginning their careers when the subject of compact objects caught fire. They have both made fundamental contributions to the field and have now given us a beautiful textbook and reference work. Above all, *Black Holes, White Dwarfs, and Neutron Stars* demonstrates the enormous range of physics that must be brought to bear in the study of astronomy, where phenomena are witnessed only in their complex entirety. Neutron stars cannot be digested piecemeal in the lab or office. Happily, Shapiro and Teukolsky's book can.

Electrical Transport in Solids

K. C. Kao, W. Hwang
663 pp. Pergamon, New York, 1981. $120.00

Electronic transport in organic solids has been a prominent topic among scientists and engineers since the early 1950s. At the Symposium on Electrical Conductivity in Organic Solids held in Durham, North Carolina, in 1960—perhaps the first international symposium exclusively devoted to electrical transport in organic solids—most of the papers concerned aromatic organic molecular crystals. In the sequel conference held in Ottawa in 1962, the role of excitons in charge-carrier generation in molecular crystals and the transport in charge-transfer complex crystals were also discussed. Research on charge-transfer complex crystals blossomed early in the 1970s, partly because of the announcement of extremely high electrical conductivity in the TTF–TCNQ complex crystal. Recently, doped organic polymers have become a focus of research interest.

In view of its importance as a research area, I have long felt the need of a good advanced text or reference book on electrical transport in organic solids. The present book, by two active research scholars, satisfies the needs of those who are interested in organic semiconductors. It covers charge-carrier injection from different contacts, space-charge electric conduction, and, in one long chapter, filamentary charge-carrier injection, high-field effects, thermally stimulated currents, transient phenomena, time-varying fields and transport in relaxation semiconductors. A chapter on photoelectronic processes begins with a concise, readable section on the molecular-orbital theory of aromatic molecules followed by a discussion of the kinetics of excitons leading to charge-carrier generation as well as a short section on the band–band transition. The authors explain photoinjection of carriers at different electrode contacts, photoemission from organic crystals and photovoltaic effects with carefully selected figures and a table summarizing photovoltaic effect measurements. In view of the central role played by the excitons in charge-carrier generation and luminescence, the final chapter on luminescence is definitely a well-conceived and useful part of the book.

K. C. Kao and W. Hwang have done an extensive literature search (over 2600 references are included) and have succeeded in coherently presenting a subject that has been investigated by a diverse group of scientists and engineers. Well-chosen figures, tables, and enough relevant equations make the book readily accessible to graduate students and researchers. The list of principal symbols makes it easy to read a section without referring back to the earlier pages.

This book is a valuable resource to any scientist or engineer who is interested in electrical transport or luminescence of semiconductors in general, as well as to anyone engaged in organic semiconductor research.

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High Resolution Spectroscopy

J. M. Hollas
638 pp. Butterworths, Woburn, Mass., 1982. $115.00

High-resolution spectroscopy has initiated most of the major advances in atomic and molecular physics. Especially over the last decade, there have been significant increases in the resolution and volume of spectroscopic data, due primarily to the development of two new tools: the laser and the synchrotron radiation source. While many of the laser spectroscopic techniques are the same as those used in traditional spectroscopy, the increased spectral brightness has extended those techniques to unexpected environments, such as low-density atomic beams and even traps for single ions. The synchrotron, in a similar fashion,