

at the graduate or advanced undergraduate level. It should be stressed, however, that playing with the simulations should not replace the hard task of learning and understanding solid-state physics, analytically and at the gut level.

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X-Ray Binaries

Edited by Walter H. G. Lewin,
Jan van Paradijs and
Edward P. J. van den Heuvel
Cambridge U. P., New York, 1997.
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ISBN 0-521-59934-2

The properties of x-ray binary star systems, as well as our present understanding of their formation and evolution, are fully discussed in the nearly 700-page volume *X-Ray Binaries*, edited by Walter Lewin, Jan van Paradijs and Edward van den Heuvel. Thirteen chapters, written by leading researchers in this field, describe the observations and theory of these bright galactic x-ray sources, among the most varied and intricate stellar phenomena known. The book also contains two catalogs, one for x-ray binaries and a second for cataclysmic binaries. Three indexes, sorted by object, author and title, greatly enhance the reader's ability to locate information. First published in hardback in 1995 and now available in paperback, *X-Ray Binaries* is an excellent reference work.

Although early observations from sounding rockets revealed the first nonsolar x-ray sources, it was not until the 1970s that optical and x-ray observations showed that x-ray sources occurred in binary systems. In these binaries, the x-ray "star" is a compact object—a neutron star, black hole or white dwarf—that accretes material from its close companion star. In the last three decades, new x-ray observations, often coupled with extensive studies in the optical, radio and ultraviolet, have led to a greater understanding of the nature, formation and evolution of these systems.

All x-ray binaries are time-variable, with scales that range from a fraction of a second to years. Study of this temporal variability probes the regions and extreme conditions of gravity, temperature and magnetic field very close to the compact object. Variability ranges from coherent, regular pulsations (from rotating neutron stars with strong magnetic fields) to quasiperiodic oscillations—which may arise as the "beat frequency" between the orbital

period of the accreting matter and the spin period of the neutron star—to the fast, erratic variability characteristic of black holes but also found in low-luminosity neutron stars.

X-ray bursts, in which the intensity can increase in seconds by factors of hundreds, can arise from thermonuclear flashes on the surface of neutron stars in low-mass x-ray binaries. Periodic variability, in the form of eclipses of the x-ray source or modulations in its intensity, also arises as the x-ray source orbits its companion star. Orbital periods are typically several hours but range from as short as a fraction of an hour to as long as weeks. Finally, x-ray transients, as their name implies, generally appear where no source was previously known. Sometimes becoming temporarily the brightest x-ray source in the sky, these transients exhibit large intensity changes on time scales of days to months.

Five chapters in *X-Ray Binaries* provide particularly well-written, well-illustrated and very well-referenced reviews of the observations. These chapters, entitled "The Properties of X-Ray Binaries" by Nicholas White, Fumiaki Nagase and Arvind Parmar, "Optical and Ultraviolet Observations" by Jan van Paradijs and Jeffrey McClintock, "Black Hole Binaries" by Yasuo Tanaka and Walter Lewin, "X-Ray Bursts" by Lewin, van Paradijs and Ronald Taam, and "Cataclysmic Variable Stars" by France Cordova, are each nearly 60 pages in length, and each incorporates hundreds of references. These chapters discuss the general characteristics of each type of binary, but they also give numerous details for individual sources. The theory of binary systems is reviewed in three chapters—"Accretion in Close Binaries" by Andrew King, "Formation and Evolution of Neutron Stars and Black Holes in Binaries" by Frank Verbunt and Edward van den Heuvel and "The Magnetic Fields of Neutron Stars and Their Evolution" by Dipankar Bhattacharya and Radhika Srinivasan.

As Cordova writes in her chapter, "A review is both an end and a beginning, summarizing the current paradigms and revealing, in the ambiguities in interpretations of observations, some areas for new explorations." *X-Ray Binaries* accomplishes the goal of providing a very complete introduction and reference source for this field, as well as illustrating important directions for future research. At present, the science of x-ray binaries continues to flourish through observations with the ASCA (Advanced Satellite for Cosmology and Astrophysics), ROSAT (Roentgen Satellite), EUVE (Extreme Ultraviolet Explorer) and RXTE (Rossi

X-Ray Timing Explorer) satellites. RXTE is primarily devoted to the detailed study of variability in x-ray binaries. EUVE and ASCA are providing spectacular spectral data for these systems. In the not-too-distant future, AXAF (Advanced X-Ray Astrophysics Facility) and XMM (X-Ray Multi-Mirror Observatory) will bring the capabilities of very high spectral resolution to the study of x-ray binaries. While much has been learned through the study of these brightest and most dynamic x-ray objects in the sky, present and future observations are expected to bring more surprises as well as solve current mysteries.

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The Role of the Sun in Climate Change

Douglas V. Hoyt
and Kenneth H. Schatten
Oxford U. P., New York, 1997.
279 pp. \$60.00 hc (\$29.95 pb)
ISBN 0-19-509413-1 hc
(0-19-509414-X pb)

Do sunspots affect the weather? That question has fascinated people for some 2400 years. And, although the scientific community has been studying this question intensively for the last 150 years, the question remains unresolved. Recent concern over the role of human activities in producing climate change has made it urgent to understand the natural drivers of climate change, including the Sun. Douglas Hoyt and Kenneth Schatten, in *The Role of the Sun in Climate Change*, review the effects that solar irradiance variations have in producing climate changes. The book summarizes both the history and our present understanding of this field, so as to provide a solid foundation for graduate students, current researchers and interested scientists in related fields. The book is easy to read, well written and hard to put down.

The authors are solar physicists. Hoyt has done extensive work on solar irradiance variations, and Schatten is known for his work on the physics of the corona, the solar magnetic field and the sunspot cycle. They begin their book by concentrating on the variability of the Sun. This question has been controversial for some time, because of the difficulty of measuring the solar irradiance with adequate precision. The authors establish that the Maunder sunspot minimum in the latter half of the 17th century was real and not

the result of a lack of observations. Additionally, they review efforts to measure time variations in the misnamed solar constant. They show that the Sun is a variable star and that the sunspot number cycle is associated with variations in total solar luminosity. The book also discusses the lives and work of the people who made the important measurements. I was particularly entertained by the description of Samuel Pierpont Langley's 1881 expedition to measure the solar constant from the summit of Mt. Whitney in Southern California.

The second section of the book deals with the history of efforts to relate changes in climate to solar activity. The authors examine the difficulties that have plagued this field. The solar sunspot number cycle has a period of approximately 11 years. Climate measurements such as temperature have to be made in ways that permit precise comparison on time scales of a hundred years or longer. Subtleties such as changes in the brand of paint used on an instrument shelter can confound the most careful investigator. Hoyt and Schatten examine these issues in considerable detail and leave the reader with an excellent feel for the topic.

The two most important problems examined by the book concern the presence of sign reversals in the observed correlations and the fact that the climate variations that are observed are larger by a factor of ten than simple energy-balance calculations can account for. The book reviews the possible explanations for these problems and is quite successful in giving the reader a well-balanced picture of the field.

The authors have chosen to consider only variations in solar irradiance as possible drivers of climate change. They discuss the role of solar ultraviolet variations on the basis that the proportional change in irradiance in the ultraviolet is much larger than it is at visible wavelengths. They do not, however, treat the solar wind, which also has a very strong solar-cycle dependence; the amplification factor required to produce climate changes is much greater for solar-wind changes than it is for irradiance changes. The role of the solar cycle in driving changes in the atmosphere at altitudes above 90 km (the magnetosphere, ionosphere and thermosphere), which they also do not consider, is well established. This omission leaves the authors unable to account for the observed 22-year periodicity in climate, which corresponds to the 22-year Hale sunspot cycle. Readers interested in this topic should consult *Sun, Weather and Cli-*

mate, by John Herman and Richard Goldberg, (Dover, 1985).

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Shadow of a Star: The Neutrino Story of Supernova 1987A

▶ Alfred K. Mann
W. H. Freeman, New York, 1997.
210 pp. \$22.95 hc
ISBN 0-7167-3097-9

In *Shadow of a Star: The Neutrino Story of Supernova 1987A*, Al Mann provides an account of the events leading to the production of neutrinos by SN1987A and their detection by two large experimental teams: the IMB collaboration working in the Morton salt mine outside of Cleveland, Ohio, and the Kamiokande collaboration working underground near the small Japanese city of Kamioka.

Mann, a senior member of the Japanese-US Kamiokande collaboration, develops two parallel stories: the evolution and explosion of Sanduleak 202, the massive star in the Large Magellanic Cloud that was the progenitor of SN1987A, and the birth and evolution of the Kamiokande experiment. While there have been several notable articles and books about stellar evolution and SN1987A, Mann's book is the only one devoted to the most exciting result to come from that remarkable celestial event: the detection of a neutrino burst associated with the supernova explosion. The observation confirmed the idea, first proposed in the 1960s by Stirling Colgate and Richard White, that the bulk of the binding energy released in the transition to a neutron star is in the form of neutrinos. This confirmed the basic notion that a type II supernova signals the end of the life of a massive star. On the experimental side, the detection of neutrinos from SN1987A was the first detection of neutrinos from outside the Solar System. (Neutrinos from the Sun have been detected since the pioneering solar-neutrino experiments of Ray Davis.)

The best part of Mann's book is the glimpse it provides of the inner workings of the Kamiokande collaboration. While the detections of atmospheric neutrinos solar neutrinos and neutrinos from SN1987A have been the great successes of the experiment, the detector was originally built for another reason: The "nde" in Kamiokande is an abbreviation for "nucleon decay experiment," not "neutrino detection experiment." The story of the tempering of the bitter disappointment in the

negative results for nucleon decay by the sweet success in the search for neutrinos is an important one: It demonstrates the ability of an experiment probing a new, unexplored domain to make discoveries not envisioned in the program's original conception.

While Mann avoids the "merely personal" (as Einstein once put it) aspects of the inner dynamics of the large collaboration, he does recount experiences with one or another of the two dozen scientists working on the Kamiokande experiment at the time of SN1987A. Although a small collaboration compared to the number of people who might be involved in particle-physics experiments, there were all the familiar problems of trying to get large numbers of independent scientists to work together toward a common goal. The story of the growth of trust and cooperation between US and Japanese groups, despite their different cultures and traditions, is something that should be read by all scientists involved in large collaborations, as well as by the public.

Mann's book certainly dispels the myth that science is a dispassionate, emotionless pursuit. The story of the events surrounding the discovery of the neutrinos from the supernova has all the drama one could hope for in an important scientific discovery. Among its human touches is the description of data transport from the detector to the collaborators on the surface: Although the data acquisition system of Kamiokande was relatively sophisticated, the data did not make its way to the surface by Ethernet or Internet, but rather by "sneakernet," as a graduate student ran with the data tapes from the underground experiment to the surface.

Shadow of a Star is intended for a general audience, and it contains valuable insights into the dynamics of large international collaborations. The detection of neutrinos from SN1987A was perhaps the astronomical discovery of the 1980s. Mann captures its excitement.

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NEW BOOKS

Astronomy and Astrophysics

Astronomical and Biochemical Origins and the Search for Life in the Universe. Proc. Conf., Capri, Italy, Jul. 1996. C. B. Cosmovici, S. Bowyer, D. Werthimer, eds. Editrice Compositori, Bologna, Italy, 1997. 814 pp. \$100.00 pb ISBN 88-7794-092-1

Instrumentation for Large Telescopes: VII Canary Islands Winter School of