

Principles of Adaptive Optics

Robert K. Tyson

Academic, San Diego, Calif.,
1991. 298 pp. \$49.95 hc
ISBN 0-12-705900-8

Most of the adaptive optics research in the last 20 years has taken place within the strategic defense community and related industry. (See the news story on page 17.) Robert Tyson has been active within this community as a senior systems engineer at United Technologies Optical Systems and more recently as a senior scientist at W. J. Schafer Associates. The publication of this book, the first on adaptive optics, occurs at a transition point for the field. The defense community is scaling down its efforts while the astronomy community is scaling up (albeit with a much smaller budget).

Astronomical science stands to benefit enormously from the application of adaptive optics to the new generation of 8-meter-class telescopes (see *PHYSICS TODAY* March 1991, page 22), which will see first light in this decade. The Astronomy and Astrophysics Survey Committee, commissioned by the National Research Council to prioritize research programs in astronomy for the 1990s, recommended adaptive optics as the highest-priority, moderate-sized ground-based program of this decade. "The prospect of improving the angular resolution of optical and infrared observations by 2 orders of magnitude over the span of a decade would be nothing short of revolutionary." (For a summary of the committee's working papers see the April 1991 issue of *PHYSICS TODAY*.)

As a researcher working on astronomical adaptive optics, I was both pleased and disappointed with this book. My mixed review reflects somewhat the multidisciplinary nature of adaptive optics and the fact that the author has had to cover a lot of ground in a single book. Tyson has brought to the book his experience as an instructor of an adaptive optics short course and as a developer and analyst of adaptive optics components and systems. *Principles of Adaptive Optics*, with the addition of certain articles referenced by the author, could be used as a textbook, although researchers in this field will probably find it most useful as a reference book. As John Hardy, one of the pioneers in adaptive optics, points out in the foreword, "today's practicing engineer is fortunate indeed to have a compendium of this hard-won knowledge." Tyson has compiled in this single source a large number of the

equations and techniques useful in adaptive optics and a valuable bibliography of over 400 articles which are referenced in the text. Unfortunately, titles of the articles are not included, many of the references are not easily accessible (this is also a comment on the history of adaptive optics) and often a conference proceeding rather than the appropriate journal article is cited. The quality of the graphics is not very satisfying, and the only photographs are of deformable mirrors.

This book is strongly influenced by Tyson's background in laser-beam propagation, although he does attempt to deal on an equal footing with astronomical applications of adaptive optics. That Tyson is not as familiar with astronomical problems and research does show from time to time, and many of the issues critical to astronomical adaptive optics, such as atmospheric characterization and laser guide stars, receive inadequate coverage.

A constant frustration for researchers in—and potential users of—adaptive optics is the scarcity of corrected images in the literature, and you won't find any in this book. The book is therefore not intended to convince people that adaptive optics work or to provide information on recent developments, especially those of a classified or proprietary nature. (The book was written prior to the May 1991 declassification.) Tyson has succeeded, however, in providing a much needed reference on the basics of the various disciplines used in adaptive optics.

PETER L. WIZINOWICH
W. M. Keck Observatory

Five Billion Vodka Bottles to the Moon

Iosif Shklovsky
(Translated and adapted
by Mary and Harold Zirin)
Norton, New York, 1991.
268 pp. \$19.95 hc
ISBN 0-393-02990-5

Iosif Shklovsky was one of the first scientists to recognize the importance of the new astronomical discoveries being made outside the traditional atmospheric window of optical astronomy. With remarkable insight and unencumbered by modern computing machines, Shklovsky used simple and elegant arguments to investigate a wide range of problems in science and life. He gave innovative interpretations of the newly discovered radio and x-ray emission from neutron stars, supernovas, galaxies and qua-

sars. Applying similar simple logic he also estimated the amount of vodka drunk each year in the Soviet Union—five billion bottles, enough to reach to the Moon—and the number of citizens being held captive in Soviet prisons. Both quantities were closely guarded state secrets.

Shklovsky loved to tell stories, especially about people he admired, like Andrei Sakharov, and those for whom he had little respect, like his boss at the Shternberg Institute, Dmitri Martinov, whom he described as a "weak-headed belligerent functionary and malicious bureaucrat." *Five Billion Vodka Bottles to the Moon* is a collection of Shklovsky's stories about the Soviet scientific establishment, bureaucracy, anti-Semitism and the daily hardships of life in Soviet society. Although copies of these essays were circulated privately in the USSR, it seemed unlikely that they would ever be published in the Soviet Union. After Shklovsky's death in 1985, his former student Nikolai Kardashev together with Shklovsky's longtime friend, x-ray astronomer Herbert Friedman, arranged for the translation and publication of Shklovsky's manuscript in English. Following the unexpected changes that have occurred in the USSR in the past few years, these essays have now also been published in the Soviet Union under the title *A Collection of Short Stories*. The English-language edition, which has been translated and adapted for English-speaking readers by Mary Zirin and Caltech solar astronomer Harold Zirin, contains 24 essays, mostly about people—close friends and detested enemies—who passed through Shklovsky's life. Herbert Friedman supplies an introduction that gives background information on Shklovsky's many contributions to astronomy and relates revealing personal experiences they shared.

Iosif Shklovsky, who was both Russian and Jewish, was outspoken about Soviet bureaucracy and politics, especially during his infrequent foreign trips. He was one of the most admired Soviet scientists in the West and received a number of foreign honors. But to his disappointment, he was denied full membership in the Soviet Academy of Sciences, remaining only a corresponding member. For much of his scientific career Shklovsky was restricted from travel abroad. Organizers of scientific symposiums often would not know until after the start of the conference if Shklovsky would receive an exit visa in time to deliver an invited paper. His book tells of the time he arrived in Paris near the end

of a UNESCO conference. Because of a bureaucratic error, he had a visa for two weeks but only enough funds for the two remaining days of the conference. With typical resourcefulness and a burning desire to see Paris, he rationed his limited resources so that he could buy a round-trip Metro ticket, a sausage and a bag of apples each day while joyfully sampling the sights and sins of Paris.

In a moving story, Shklovsky portrays his 1941 escape from the German attack on Moscow in a train crowded with other students from Moscow University. One of the undergraduates in his train car asked Shklovsky, the senior member of the group, for a physics book to read. Mischievously, Shklovsky gave the young student a German-language copy of Walter Heitler's *Quantum Theory of Radiation*, difficult reading under the best of circumstances. With obvious admiration, Shklovsky, who claimed he "couldn't get through the first paragraph," tells of his surprise when the book was later returned by "the kid," who had apparently read the whole volume with complete understanding. Shklovsky relates how 30 years later he presented the same miraculously preserved book, to that former student on the occasion of the latter's 50th birthday. The recipient was Andrei Sakharov. Curiously, in his own memoirs, Sakharov tells of reading Shklovsky's then unpublished story, but he denies that the event in the train ever occurred. Such is the imperfect memory of great men.

Five Billion Vodka Bottles to the Moon is required reading for anyone—scientist, politician or concerned human being—who wants to understand better the unexpected events now occurring in Russia.

KENNETH I. KELLERMANN

National Radio Astronomy Observatory

Fractional Statistics and Anyon Superconductivity

Frank Wilczek

World Scientific, Teaneck, N. J., 1990. 447 pp. \$68.00 hc ISBN 981-02-0048-X; \$28.00 pb ISBN 981-02-0049-8

The quantum mechanics of many-body systems revolves around the requirement that simply relabeling indistinguishable particles cannot alter an observable quantity. In three or more spatial dimensions this restriction permits only two classes of particles—bosons and fermions—depending on whether permuting a pair is accompanied by a phase factor of

plus or minus one. A unique feature in two spatial dimensions is that one can keep track of the number of times a particle has encircled another; the principles of quantum mechanics are then consistent with associating a phase with each encirclement. This phase factor is not constrained *a priori*, and it specifies a continuum of possible quantum statistics in two dimensions (in the same way that the ± 1 factor for exchange specifies the two possibilities in higher dimensions). (See *PHYSICS TODAY*, November 1989, page 17.) Excitations that possess these intermediate statistics, dubbed anyons, are found in the fractional quantum Hall effect. Anyons arise naturally in $(2+1)$ -dimensional quantum field theories, and they have recently aroused interest as possible charge carriers in doped copper oxides.

Frank Wilczek's *Fractional Statistics and Anyon Superconductivity* offers a lucid introduction to the elementary physics of anyons. In a relaxed, conversational style, Wilczek leads off the volume with a pair of monographs that discuss the conceptual and formal underpinnings of fractional statistics and address the physics of many-anyon systems. The last three-quarters of the book consists of over two dozen articles reprinted by Wilczek and others.

Since the phase factor associated with carrying one anyon around another specifies the allowed relative angular momentum of a pair, a many-anyon wavefunction must satisfy cumbersome boundary conditions that force it to be multivalued. A more economical way to introduce the required phase factors is by means of the Aharonov-Bohm effect—for example, by formulating anyons as charged fermions (or bosons) attached to magnetic flux lines of the appropriate strength. Wilczek deftly leads the reader through the subtleties of this procedure and shows how fractional statistics arise naturally in $(2+1)$ -dimensional quantum field theories with Hopf and Chern-Simons terms as their Lagrangians.

Readers seeking further insight into the conjectured relationship between anyons and high-temperature superconductivity may be somewhat disappointed. The "anyon superconductivity" of the title refers to the superfluidity of certain ideal anyon gases, which support long-lived longitudinal sound modes (and can therefore carry persistent currents) and have a gap to transverse excitations (permitting only irrotational superflow and implying the expulsion of external magnetic fields). As Wilczek

notes, the proposed connection between anyon gases and electrons in copper oxides remains quite tenuous, and the discussion of these issues is found primarily in the book's reprinted articles on chiral spin liquids.

Experiments to detect the breaking of time-reversal and reflection symmetries in high-temperature superconductors (which would necessarily arise if anyons were involved) are not encouraging for anyon models. (See *PHYSICS TODAY*, February 1991, page 17.) A complete discussion of the role of anyons in high-temperature superconductivity (if any) will have to wait for a future edition.

Aficionados of fractional statistics will find many of their favorite articles reprinted here—from Yakir Aharonov and David Bohm's classic 1959 paper on vector potentials in quantum mechanics to Xiao-Gang Wen, Wilczek and Anthony Zee's 1989 work on chiral spin liquids. Because it is the best-known physical phenomenon displaying anyonic excitations, the fractional quantum Hall effect is prominently featured, as are several papers concerning frustrated-spin systems and the superconductivity of anyon gases. These reprints complement an extensive selection of articles on the conceptual and technical foundations of fractional statistics.

This timely volume offers a clear introduction to the rudiments (and some of the esoterica) of fractional statistics. It should be accessible to anyone with a graduate-level background in quantum mechanics and elementary field theory. In addition to guiding the reader around the "circle of ideas" associated with fractional statistics and anyon superconductivity, the book also provides a thought-provoking refresher course in superfluidity and the quantum mechanics of indistinguishable particles.

DANIEL S. ROKHSAR

University of California, Berkeley

Space Commerce

John L. McLucas

Harvard U. P., Cambridge, Mass., 1991. 241 pp. \$24.95 hc ISBN 0-674-83020-2

John McLucas defines space commerce as "those activities in which private companies put their money at risk to offer goods and services that depend on having satellites in orbit." In this book he includes chapters on communications satellites, remote sensing, navigation, habitations in space and materials processing. I found his accounts of these develop-