and-white radio images. Radioastronomy has become the equal of optical astronomy in the range and quality of astronomical information it makes accessible.

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Radiotelescopes

W. N. Christiansen and J. A. Högbom
Cambridge U. P., New York, 1987 [1985]. Second edition. 265 pp.
$24.95 pb ISBN 0-521-34795-5

Interferometry and Synthesis in Radio Astronomy

A. Richard Thompson, James M. Moran and George W. Swenson Jr
Wiley, New York, 1986. 534 pp.
$59.95 hc ISBN 0-471-80614-5

Tools of Radio Astronomy

Kristen Rohlfs
Springer-Verlag, New York, 1986. 319 pp.
$62.00 hc ISBN 0-387-16188-0

Exploration of astrophysical sources with the five decades of the electromagnetic spectrum between 100 m and 1 mm requires a wide variety of techniques, which are unified in the field of radioastronomy.

Radioastronomy developed in three phases. Before World War II the pioneers, Karl Jansky and Grote Reber, detected the first radio signals from beyond the solar system. The development of radar during the war led to a rapid expansion of the field afterwards, when scientists returned to their academic institutions. The third phase began in the 1960s, when sophisticated multiple-aperture telescopes were developed that could provide radioastronomers with resolutions exceeding the highest resolution of optical telescopes. The three books reviewed here provide texts for the modern student and researcher.

Radiotelescopes by W. N. Christiansen and J. A. Högbom is an attractively printed and welcome second edition of a classic 1969 monograph on the variety of antenna systems that have been developed for radioastronomy. Most of the chapters differ little from those of the first edition. The introduction, which summarizes the scientific needs that motivate the instrumental developments, and the chapter on aperture synthesis have been extensively revised, to reflect the developments in the past two decades.

The properties of filled-aperture antennas, especially the popular parabolic reflector, receive very thorough treatment. This includes the effect of aperture illumination on antenna pattern and the effect of surface imperfections caused by manufacturing errors and by gravitational, thermal and wind forces. There is discussion of the advantages and disadvantages of prime focus and Cassegrain feeds and the different mountings of antennas. While the authors suggest that spherical reflectors with aberration corrections may be important in the future, they do not describe the Gregorian reflector solution that is proposed for the US National Astronomy and Ionosphere Center's 1000-ft spherical reflector at Arecibo, Puerto Rico.

The especially valuable concept of the antenna as a spatial filter is introduced in the sections on correlation telescopes, whose apertures are largely unfilled. The idea of spatial frequencies is explained naturally through the use of the Fourier transform. This presentation unifies the discussion of the very diverse instruments that have been built: the grating arrays, the crosses, the Tees, the rings and the basic aperture-synthesis arrays. Christiansen himself developed many of these designs. The Fourier transform concept not only helps to explain these various instruments but also gives the reader an essential tool for the design of new antenna systems.

In the nearly 20 years since the appearance of the first edition, the majority of new high-resolution instruments have been interferometers that carry out Earth rotation synthesis. The trend has been away from hardware image formation to computer image processing and enhancement. The development of powerful general purpose computers has enabled many important advances. Mapping with dynamic ranges better than 1000:1 is now commonplace, as is the achievement of excellent maps with the very sparse sampling obtained with very-long-baseline interferometry. *Radiotelescopes* contains a clear discussion of the effects of irregular sampling and of the various image processing techniques that have been invented to remove confusing instrumental effects from radio maps. The presentation would be improved by more examples. Image processing is the area in which there have been the greatest recent technical advances in radioastronomy. The lack of detail is all the more surprising because Högbom wrote the seminal paper (*Astrophys. J. Suppl.* 15, 417, 1974) in this area.

Interferometry and Synthesis in Radio Astronomy by A. Richard Thompson, James M. Moran and George W. Swenson Jr is a comprehensive account of techniques, written by three highly respected practitioners. Much of this material is not available in any other text, and many of the topics are treated at a level that is otherwise available only in journal articles, or, as the authors mention in their preface, in unpublished reports, observatory memoranda and lecture notes. What the readers do not find in this text, they will find in the extensive bibliographies and reference lists that follow each chapter.

The emphasis in Thompson, Moran and Swenson's book is on many aspects of the two-element radio interferometer. Half of the book develops an analytic description of the response of a pair of radiotelescopes to a distribution of partially polarized electrical noise signals on the celestial sphere. A measure of the detail to be found in these chapters is illustrated by the description of the effects on measurements of the offset between the two rotation axes of some telescopes. The authors cover both the propagation of the signals through the individual antenna elements and the correlation of signal pairs. They concentrate on techniques now in use on cm- and mm-wavelength interferometer arrays.

While Thompson, Moran and Swenson present the topic of aperture synthesis by Earth rotation and by physical movement of telescopes in greater detail than Christiansen and Högbom, their sections on synthesis are slight when compared with the effort that users expend in wrestling with data. However, other accounts, such as review articles, conference proceedings and observatory handbooks, deal with these topics.

Very-long-baseline interferometry is a frontier of development today, with the Very Long Baseline Array now under construction by the National Radio Astronomy Observatory and corresponding efforts proceeding around the globe. The field has progressed through many phases as the fundamental possibilities of correlating signals from observatories without a real-time connection were realized by detailed analysis and implementation. The techniques of interferometry and synthesis that are special to VLBI are succinctly presented.

One of the highlights of the book is the chapter on propagation, which

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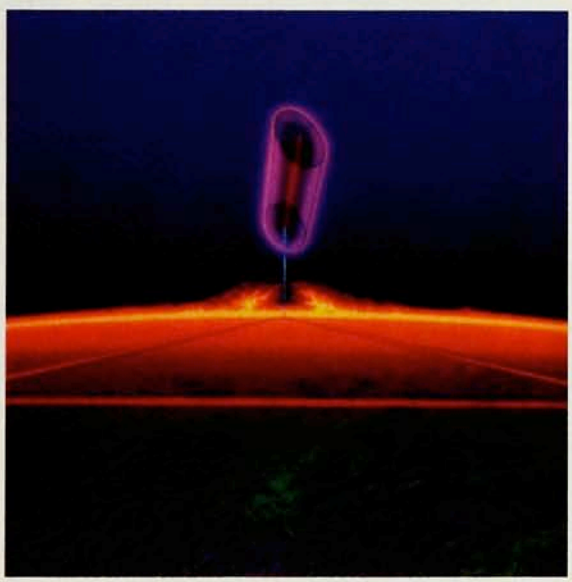

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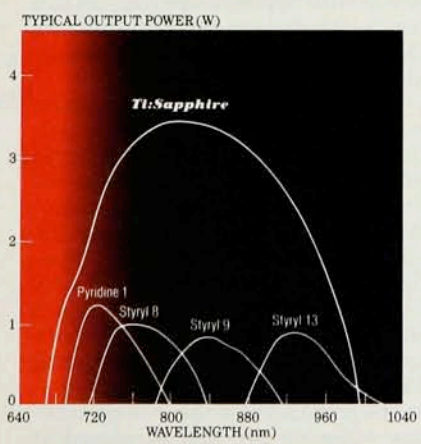

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presents the basic physics of the influence of both neutral and ionized media on radio signals. There are many equations and figures that will be useful to an observer as reference material.

Tools of Radio Astronomy by Kristen Rohlfs first presents the fundamental principles and measurement techniques that are the topic of the other books, and then focuses on the physical interpretation of the data. The emphasis is on cm-wavelength astronomy with single telescopes rather than the higher-resolution interferometric approach.

An outline of the theory of electromagnetic waves and their propagation through an ionized plasma opens the first half of the book. This is followed by discussion of the application of this theory to antennas, including both interferometers and parabolic telescopes. Finally, there are a succinct, well-developed section on signal processing and brief discussions of the fundamentals of receivers, mixers and spectrometers. This summary of all technical aspects of radioastronomy is the broadest among the three texts.

The second half of the book deals with the astrophysical interpretation of data. Two primary continuum emission mechanisms, thermal bremsstrahlung and nonthermal synchrotron radiation, are derived from first principles. The detail of the derivations is appropriate for this kind of book: The finer points involving detailed mathematical analysis are omitted, but the basic physical principles are emphasized with full rigor. Rohlfs then applies these theories to a few "textbook" examples to illustrate the basic observational results to be expected.

The discussion of synchrotron emission of an individual particle is particularly useful, because it succinctly presents the full range of physical principles required for a full understanding of the process. However, the absence of topics such as the "low-frequency turnover," which results from either opacity or diffuse plasma effects, and the evolution of the energy distribution of emitting particles is disappointing.

The physical principles of spectral-line radiation are first developed at an appropriate level, and then applied to the 21-cm hydrogen line and to recombination lines. Rotational and vibrational spectra of molecules are briefly treated, and considerable detail is given regarding 2.6-mm emission from the abundant molecule CO. While the absence of further information on mm-wavelength spectral transitions of molecules is reasonable given the book's emphasis on cm wavelengths, Rohlfs gives little information on molecules that emit at cm wavelengths. A table of molecules, line frequencies, transition probabilities and energy levels involved in at least the most important cm-wave molecular transitions would have improved this part of the text. The theoretical treatment of interstellar masers, again at a nice level of detail, surprisingly is not accompanied by a discussion of the important masers: OH, H_2O and CH_3OH.

The three books serve quite different purposes. Christiansen and Högbom's book provides a broad coverage of most instrumental topics germane to radiotelescopes. Thompson, Moran and Swenson's is a densely packed reference book for all aspects of interferometry and aperture synthesis, one that we are all glad that "someone" has written. Rohlfs's *Tools* presents basic topics in radioastronomy that cover both instruments and astrophysics. The former two would be appropriate for a techniques-oriented graduate course, while the latter is designed for a broader survey of radioastronomy. *Interferometry and Synthesis* is the most important technical source book available for practicing astronomers and observatory staff.

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Astronomical Tables of the Sun, Moon and Planets. J. Meeus. Willmann–Bell, Richmond, Va., 1983. *Ca.* 370 pp. $19.95 *pb* ISBN 0-943396-02-6. *Reference*

Astrophysics and Space Physics Reviews, Vol. 6: Parts 1–5. *Soviet Scientific Reviews: Section E.* R. A. Syunyaev, ed. Harwood Academic, New York, 1988. 575 pp. **Part 1: The Phobos Project.** $43.00 ($21.00, SAS members) *pb* ISBN 3-7186-4837-7. **Part 2: Cosmology.** $39.00 ($20.00, SAS members) *pb* ISBN 3-7186-4838-5. **Part 3: Supernovae.** $50.00 ($25.00, SAS members) *pb* ISBN 3-7186-4839-3. **Part 4: Nuclear Processes in the Solar Atmosphere and the Particle-Acceleration Problem.** $50.00 ($25.00, SAS members) *pb* ISBN 3-7186-4840-7. **Part 5 [Space Plasma Physics].** $61.00 ($31.00, SAS members) *pb* ISBN 3-7186-4841-5