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978-0-521-87808-1 - An Introduction to Radio Astronomy, Third Edition

Bernard F. Burke and F. Graham-Smith

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AN INTRODUCTION TO RADIO ASTRONOMY

Third Edition

Written by two prominent figures in radio astronomy this well-established, graduate-level textbook is a thorough and up-to-date introduction to radio telescopes and techniques. It is an invaluable overview for students and researchers turning to radio astronomy for the first time.

The first half of the book describes how radio telescopes work – from basic antennas and single-aperture dishes through to full aperture-synthesis arrays. It includes reference material on the fundamentals of astrophysics and observing techniques. The second half of the book reviews radio observations of our Galaxy, stars, pulsars, radio galaxies, quasars and the cosmic microwave background.

This third edition describes the applications of fundamental techniques to newly developing radio telescopes, including ATA, LOFAR, MWA, SKA and ALMA, which all require an understanding of aspects specific to radio astronomy. Two entirely new chapters now cover cosmology, from the fundamental concepts to the most recent results of WMAP.

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Preface

Astronomy makes use of more than 20 decades of the electromagnetic spectrum, from radio to gamma rays. The observing techniques vary so much over this enormous range that there are distinct disciplines of gamma-ray, X-ray, ultraviolet, optical, infrared, millimetre and radio astronomy, often concentrated in individual observatories. Modern astrophysics depends on a synthesis of observations from the whole wavelength range, and the concentration on radio in this text needs some rationale. Apart from the history of the subject, which developed from radio communications rather than as a deliberate extension of conventional astronomy, there are two outstanding characteristics that call for a special exposition. First, the astrophysics: long-wavelength radio waves are most often observed as a continuum in which the interaction with matter follows classical electrodynamics. High-energy electrons are involved; they are created in a variety of circumstances, and their radiation as they circulate in magnetic fields gives evidence of new phenomena, often showing a close link to the phenomena observed in X-rays and gamma-rays. At the shorter wavelengths the low quantum energy gives access to spectral lines from atomic and molecular species at comparatively low temperatures. Second, the techniques: radio astronomy takes account of the phase as well as the intensity of incoming radio waves, allowing the development of interferometers of astonishingly high angular resolution and sensitivity.

The third edition of this *Introduction* was stimulated by recent remarkable advances both in techniques and astrophysics. Without question the most important advance has been in the observations of the cosmic microwave background by the WMAP satellite. We present the results of the 5-year data reductions, which give a large number of fundamental cosmological constants with unprecedented accuracy. Also, a new generation of radio telescopes, with dramatically improved performance, is under construction, most of them such large enterprises that they necessarily involve international collaboration. The techniques follow well-established principles, but the advent of massive computer power and broad-band fibre-optic communications has only recently brought these schemes within the range of possibility. At the same time, the success of existing telescopes has shown what can be achieved by the new telescopes in several astrophysical domains, such as pulsars and black-hole physics, and particularly in addressing fundamental cosmology.

We aim therefore to extend our exposition of the fundamentals of radio astronomy in two directions, cosmology and technology. The cosmological discoveries of WMAP

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demonstrate new directions for CMB measurements, with polarization having particularly strong potential. The techniques of aperture synthesis have developed to allow the use of very large collecting areas. With the ever-advancing technology of digital circuits and wide-band, low-noise amplifiers, the attendant increased sensitivity and high angular resolution, including wide field coverage, open new areas of astrophysical research. These instruments will demand the efforts of a large work force, and they will provide material for a large new body of observers and astrophysicists. Our aim is to provide a basic introduction for this expanding community.

The plan of the book is twofold: we hope that the scope and impact of radio-astronomy observations will be demonstrated in the astrophysical discussion, and at the same time we intend to give a brief but comprehensive treatment of the elegant technologies that have developed. The breadth of the subject matter necessarily limits the length of the treatment for each subject; we have tried, therefore, to provide recent, comprehensive references to the extent that they are available. Cosmology, and especially the study of the cosmic microwave background, has been transformed in the last decade; here we have attempted a basic exposition as well as a presentation of the astounding conclusions from recent observations.

In addition to the astronomy graduate student and those professionally committed to radio astronomy, there is a wider audience for whom this book is intended: the interested astronomers from outside the field who want to be informed of the principal ideas current in radio astronomy, and may even be thinking of carrying out radio observations that would complement other work in progress. Even though we have mainly kept our discussions within the boundary of radio astronomy for the sake of convenience, everyone is aware that the boundaries between disciplines have dwindled in importance. Radio observations would have been a baffling puzzle if the optical identifications of sources had not been made, and both radio and X-ray astronomers have long been aware of their kinship, since both study high-energy phenomena, though at the opposite ends of the spectrum. The techniques vary, but the astronomer of the future should have access to the entire electromagnetic spectrum.

The text of this third edition has been extensively rewritten, especially in the important technical areas of interferometry and aperture synthesis and in most areas of astrophysics and cosmology. Keeping up with such a rapidly moving subject is impossible, but we have taken the advice of many colleagues, and have attempted to keep to the original objectives. We hope we have succeeded in providing an introduction that is useful both to the observer and to the astrophysicist; perhaps it will appeal most to those who, like ourselves, enjoy membership of both categories.

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