promises to reward us with an understanding of the outer atmospheres of the sun and stars.

ELLEN ZWEIBEL
Department of Astrophysical, Planetary, and Atmospheric Sciences, University of Colorado, Boulder, CO 80309

Very Luminous Objects

Active Galactic Nuclei. R. D. BLANDFORD, H. NETZER, and L. WOLTJER. Springer-Verlag, New York, 1990. xii, 280 pp., illus. $49.50. Saas-Fee Course 20, Lecture Notes 1990.

The active galactic nuclei (AGNs) are the most luminous objects in the universe. Many have power outputs in excess of a trillion times that of the sun, and this energy generation occurs in a region no larger than the solar system. They are the most distant objects visible: the furthest ones emitted their light when the universe was only 10 percent of its present age. Since their discovery 30 years ago, the central questions have remained the same: How do they make their energy, and can they be used as probes of conditions and evolution in the early universe?

This work is based on a series of lectures given by the three authors. The first section, by Woltjer, nicely sets the stage for what follows. It describes the range of phenomena we hope to understand, including the various subclasses of AGN (the quasars, Seyfert galaxies), and provides a census of their population.

The second section, by Netzer, outlines the interpretation of the ultraviolet and optical spectrum. Careful analysis of the emission lines, and the underlying continuum, is the only way we can hope to be able (someday) to measure the chemical composition and luminosity of an AGN directly. Then it will be possible to determine the chemical enrichment of the earliest galaxies and the deceleration of the universe by observing quasars at high redshift. The problem is one in nonequilibrium thermodynamics, since this is the physical state of the gas making the observed spectrum. Netzer is a leader in the numerical simulation of the emitting regions of AGNs, and this section of the book is certain to become a much-quoted reference for studies of the emission-line regions.

The last section, by Blandford, tackles the most difficult problem of all, how and why the AGNs emit so much energy. Quasars were most common in the distant past, when galaxies were being formed. The release of gravitational potential energy, as matter is accreted into the center of a galaxy, is thought to play a major role in producing energy. Blandford is a leader in non-thermal processes and helped develop today's "standard model" of AGN energy generation near supermassive black holes. The theoretical discussion is nicely integrated with the observational consequences, so this section will be a useful aid for both observations and theory.

This book will become the definitive graduate text on AGNs. The attempt to understand a phenomenon such as AGNs cannot be limited to specialized subfields such as radio astronomy or numerical hydrodynamics, and it would be impossible for any one person to combine the breadth of expertise found here. The editors have done a nice job of tying the three sections together. Although there are other review articles that compare in some way to each of the three sections of this book, there is no single place where an effort has been made to bring things together in a coherent manner.

GARY FERLAND
Department of Astronomy, Ohio State University, Columbus, OH 43210–1106

Dark Matter

Molecular Clouds. R. A. JAMES and T. J. MILLAR, Eds. Cambridge University Press, New York, 1991. xxii, 336 pp., illus. $59.50. From a conference, Manchester, U.K., March 1990.

We tend to associate astronomy with the study of stellar objects, which are visible by their own emitted light, or, closer to home, of planetary objects, which are visible by reflected sunlight. The universe, however, has a comparable amount of "dark matter" that is of equal importance astronomically but that is, perforce, more difficult to study. Simple consideration of cosmic elemental abundances suggests that 90 percent of this matter is hydrogen. The distribution of atomic hydrogen is now reasonably well known from radiofrequency observations of its fine structure transition at a wavelength of 21 centimeters. Observation of molecular hydrogen is more difficult. Cold H_2 can be observed via ultraviolet electronic absorption lines, but only from above the atmosphere and against appropriate continuum sources. Hot H_2 can be observed via weak infrared vibrational emission lines, but these also suffer from telluric obscuration. Nonetheless, the existence of large amounts of H_2 in "dense molecular clouds" was inferred in the 1970s from radiofrequency and microwave observations of a myriad of trace molecular species, the most abundant of which is carbon monoxide. Study of this molecular interstellar gas is now an important subdiscipline in astrophysics.

Despite the current vitality of molecular radioastronomy (or perhaps indeed because it is still evolving so rapidly) there are few volumes that provide a good overview of the subject, although several reviews treating various aspects are available in the periodical literature. An attempt to provide a comprehensive collection of survey articles was reviewed recently in these pages (26 October 1990, p. 576). As in any active field there are frequent international conferences, the proceedings of which can provide a glimpse into current activity. *Molecular Clouds* contains the proceedings of such a conference held a year ago. The volume is very much a mixed bag, with nearly a dozen invited review talks and about two dozen each of short contributed papers and poster presentations. The latter two categories are essentially primary literature unlikely to interest those who do not regularly scan the *Astrophysical Journal.*

What I found most interesting about this volume is the picture that emerges of the pivotal role of carbon monoxide for tracing the invisible hydrogen gas and the problems associated with quantifying the relationship between them. There have been two large-scale surveys of CO emission, confined mainly to the Galactic plane, and one of these is discussed in some detail in the somewhat historic and chatty introductory review by Thaddeus. Blitz surveys complementary CO observations away from the Galactic plane. In fact, half the papers here discuss observations of CO. Despite a wealth of data, the appropriate method of inferring hydrogen mass from CO line intensities remains controversial, although there is general agreement that the ratio is not a universal factor but depends on a number of local parameters. A basic problem is that calibration requires an independent means of determining the hydrogen mass for at least some regions where CO is observed. The most thorough studies to date use infrared or gamma-ray surveys for this. The infrared surveys measure mostly dust particles associated with the gas, so some assumption about the gas-to-dust ratio is necessary. The gamma-ray surveys measure the product of local matter density and (the somewhat uncertain) cosmic ray flux. Differing perspectives on these and other methods are found in papers by Bloemen and by Wolfendale. Since the calibration studies have relied mainly on data from our own Galaxy, their utility for interpreting the very interesting extragalactic data is an important question, and this is discussed cogently by Booth, who also gives arguments