

CASTING MUCH LIGHT ON INTERSTELLAR MATTERS

Astrophysics of Gaseous Nebulae and Active Galactic Nuclei

Donald E. Osterbrock
University Science Books, Mill
Valley, Calif., 1989. 408 pp.
\$36.00 hc ISBN 0-935702-22-9

Reviewed by J. Michael Shull

Nebulae are bright patches of diffuse emission in the night sky produced by interstellar gas heated and ionized by energetic photons or fast shock waves. Their spectra reveal continuous emission and a wide range of emission lines from hydrogen, helium and many trace heavy elements. Included in the nebula category are "H II regions" (ionized regions around hot young stars), planetary nebulae around hot white dwarf stars, novae and supernova remnants, and even gas clouds surrounding supermassive black holes in the nuclei of active galaxies. According to Donald Osterbrock, no subject in astrophysics has contributed so much to our understanding of the universe as the study of gaseous nebulae.

Osterbrock is a former director of Lick Observatory. His earlier book *Astrophysics of Gaseous Nebulae* (Freeman, San Francisco, 1974), commonly known to astrophysicists as "AGN," has been a standard graduate textbook in the fields of interstellar and nebular astronomy. In its nine chapters, it described the physics of photoionization, thermal equilibrium, radiative transfer, internal gas dynamics and the emission from photo-

ionized nebulae. Furthermore, it provided newcomers to the field with a "cookbook" on how to construct models of these nebulae for comparison with observations at visible or radio wavelengths.

Osterbrock's most recent book has been termed (AGN)², a play on the common abbreviation for "active galactic nuclei." These AGNs, including quasars and Seyfert galaxies, are among the most energetic and physically exotic astronomical sources, with emission-line spectra similar to those of gaseous nebulae. The standard model for AGNs presumes the existence of a supermassive black hole in the nucleus of a galaxy, surrounded by a circulating flow of dense gas (the "accretion disk") and by a myriad of gaseous clouds photoionized by the ultraviolet and x-ray photons produced by radiative processes in the disk and near the black hole. As the clouds absorb and reprocess the ionizing photons, they are heated to temperatures between 10 000 and 30 000 K and re-emit the absorbed energy in characteristic emission lines spread from the visible to the ultraviolet portion of the spectrum. The ensemble of gas clouds is commonly known as the "broad-line region" of the AGN, owing to the observed broad spectral lines that presumably result from the Doppler shifts of the clouds' trajectories near or within the galactic nucleus.

The first nine chapters of (AGN)² are revised versions of the nine chapters of the earlier book. Osterbrock has performed an invaluable service by updating the tables of observational results and atomic data. Particularly useful are the tables of collisional-excitation and radiative transition probabilities for important emission lines and of the photoionization cross sections and recombination rate coefficients for astrophysically abundant ions. References to original articles are conveniently provided at the end of each chapter. With the tables and text, the reader sees at first

hand the immense theoretical architecture behind the casual phrase "plasma density and temperature diagnostics."

Osterbrock is a traditional optical astronomer and has a definite flair for historical context. The book provides excellent references to the classical papers in the field and to current observations. The text could possibly have been improved by including a deeper discussion of the infrared, ultraviolet and x-ray spectroscopy of nebulae. However, Osterbrock notes in his preface that he gives only brief mention to the X-ray and radio radiations from AGNs, and one can surmise that the need to limit the book's length and cost played a role in this decision.

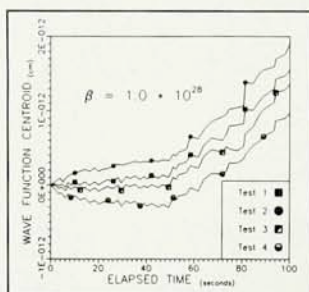
The new text does describe the physical diagnostics provided by some ultraviolet lines (such as the important semi-forbidden lines of twice-ionized carbon, C²⁺ at 1907 and 1909 Å, and the ultraviolet resonance lines of C⁺, C³⁺ and Mg⁺). The chapter on the internal dynamics of H II regions provides a new discussion of non-spherically symmetric models of the ionized gas around hot, massive stars near interstellar molecular clouds, and the chapter on interstellar dust makes a foray into recent observations at ultraviolet wavelengths.

The last three chapters are completely new: one on nova and supernova remnants and two on the emission-line spectra from ionized gas in active galactic nuclei. These chapters are succinct, and they clearly demonstrate some applications of emission-line spectroscopy. The supernova chapter manages to cover a wide range of material, but still is just an introduction. The references provide an excellent start for in-depth study, although they do omit the important observational and theoretical studies of x-ray emission lines from shocked heavy elements ejected from the exploding star in young remnants.

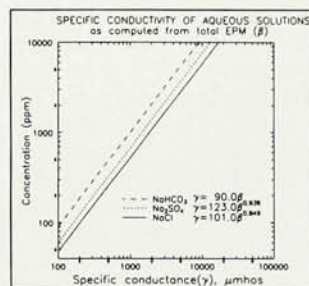
The two chapters on active galactic nuclei are outstanding, and are ideal

J. Michael Shull is a professor of astrophysics at the University of Colorado and the Joint Institute for Laboratory Astrophysics. His research interests include studies of interstellar and intergalactic matter, quasars, supernovae, ultraviolet and x-ray space astronomy, and the applications of atomic and molecular data to astrophysics.

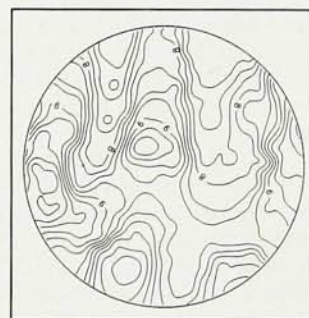
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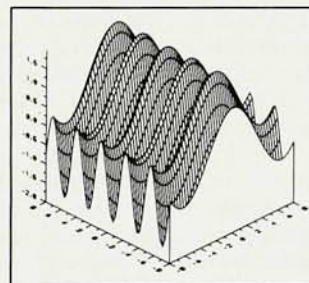
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for introducing astronomers to the wealth of optical observations on these objects and to their physical interpretation. Astronomers are on a much weaker footing in modeling quasars than in modeling other nebulae, because the great distance to quasars precludes obtaining a "picture" of an AGN broad-line region. One is therefore forced back on theoretical models and spectral diagnostics. These two chapters provide valuable discussions of these diagnostics and how they are used to build models of the distribution and nature of gas in these regions. Osterbrock's book could work well in complement with Lyman Spitzer's text, *Physical Processes in the Interstellar Medium*, with its extensive discussions of gas dynamics, shocks and thermal physics of nebulae.

One leaves the text wishing for many more chapters on quasars and Seyferts. However, that is probably because one feels so expertly prepared by what has been provided. Osterbrock's new book is a tribute to the power of "nebular physics" in interpreting the physical conditions around many astrophysical objects. The book does its job very well, and I highly recommend it.

J. MICHAEL SHULL

University of Colorado and Joint
 Institute for Laboratory Astrophysics

The Structure and Interpretation of Quantum Mechanics

R. I. G. Hughes

Harvard U. P., Cambridge,
 Mass., 1989. 370 pp.

\$39.50 hc ISBN 0-674-84391-6

Because of its radical departures from classical physics, quantum mechanics and its interpretation have long attracted the attention of philosophers. Unfortunately, it has not been possible to state the essence of quantum theory in informal, nonmathematical terms. Philosophers who have not mastered the mathematical formalism are therefore at a severe disadvantage in trying to understand the interpretation and significance of the theory. In the past the philosophers have tended to take the assertions of physicists as gospel and have devoted much of their effort to interpreting the meaning of the words written by the founders. Gospel, unfortunately, is not always a reliable guide to truth, and this method of exegesis of the canonical texts of Niels Bohr, Werner Heisenberg and others did not lead to a satisfactory solution of the problems

of interpretation of quantum theory.

"No real insight into quantum theory is possible without an acquaintance with the mathematics it employs," says R.I.G. Hughes (an associate professor of philosophy at Yale) in the opening sentence of part 1 of *The Structure and Interpretation of Quantum Mechanics*, on the mathematical structure of quantum theory. This assertion sets the tone for the book and places the author's attitude much closer to that of a physicist than to that of the older generation of philosophers, who gave us seemingly endless verbal analyses of concepts like causality and complementarity.

It is part 2, on the interpretation of quantum mechanics, that is most interesting to me. Here I would identify three major results. The first is rooted in the Einstein-Podolsky-Rosen argument of 1935, now superseded by John S. Bell's 1964 theorem. It establishes—or appears to establish, for alternative views are sometimes proposed—a conflict between the predictions of quantum theory and the demand that there be no instantaneous nonlocal causation. The second is rooted in Schrödinger's cat paradox, also from 1935, now succeeded by the analysis of quantum mechanical measurement processes. It demonstrates that quantum uncertainties can not be confined to the microscopic domain. If a macroscopic apparatus measures some observable, and if the initial state of the measured object is not an eigenstate of that observable, then according to the linear Schrödinger equation the final state of the system (that is, object plus apparatus) will be a coherent superposition of macroscopically distinguishable states (that is, a superposition of apparatus pointer-position eigenstates). The third is the 1965 theorem by Simon Kochen and E. P. Specker, which shows that it is not possible to assign instantaneous values to all observables if they are constrained to satisfy certain relations involving only commuting sets of observables. To be viable an interpretation of quantum mechanics must be compatible with these three results.

Among physicists Bell's theorem is the best known of the three. It is discussed in Hughes's book, but does not play a major role in the argument. Hughes recognizes the importance of the measurement problem, but his response to it does not seem satisfactory (as I shall discuss below). The Kochen-Specker theorem has received more attention from philosophers than from physicists, and it (along with A.M. Gleason's related theorem) sets the tone for the second