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With 208 Figures

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Preface

The purpose of this book is to address the growing recognition of the need for plasma physics in astrophysics. In fact, astrophysics has contributed to the growth of plasma physics, especially in the field of plasma waves. During the last decade, plasma physics, or more appropriately, plasma science, has witnessed an explosive growth in two areas: pulsed-power technology and space physics. Both have led to knowledge that is mutual and complementary, and the material in this book largely derives from these new discoveries and their application to astrophysics. With the passage of the Voyager spacecraft in 1989, Neptune was transformed from an astronomical object to a space science object. In our solar system, only Pluto remains unvisited. In this decade of exploration, the solar system has become recognized as the primary plasma laboratory in which plasma processes of great generality and astronomical significance can be studied in situ. By the 1960s, with the discovery of the earth's natural plasmas, the Van Allen radiation belts, and the solar wind, it was already clear that future understanding of the earth and sun would be expressed in terms of plasmas. Today plasma is recognized as the key element to understanding the generation of magnetic fields in planets, stars, and galaxies; phenomena occurring in stellar atmospheres, in the interstellar and intergalactic media, in radio galaxies, in quasars, and in active galactic nuclei; and the acceleration and transport of cosmic rays. There are convincing arguments for the view that the clouds out of which galaxies form and stars condense are ionized: The problem of the formation and structure of these clouds and bodies, therefore, naturally belongs to the field of cosmic plasmas as well as astrophysics. Each has traditionally been pursued independently. Only recently has there been a tendency to view them as a unified discipline.

Together these problems form what is called *The Plasma Universe*, the basis for this book. The material presented dwells basically on the known properties of matter in the plasma state. Some of the interesting topics in contemporary astrophysics such as discordant redshifts and other cosmological issues are not discussed here. The interested reader will be referred to the *IEEE Transactions on Plasma Science*, Special Issues on Space and Cosmic Plasmas (December 1986, April 1989, and February 1990), and *Laser and Particle Beams* (August 1988).

This book is organized into eight chapters. Chapter 1 is an introduction to the fundamental physics of cosmic plasmas. An attempt is made to review the known properties of plasmas from the laboratory scale to the Hubble distance. Chapter 2 starts the application of basic plasma theory to astrophysical plasmas in the study of magnetic-field-aligned (Birkeland) currents and charged particle beams. Chapter 3 covers magnetism in plasma and the Biot–Savart force law, while Chapter 4 concentrates on electric fields in space and cosmic plasmas. Chapters 5, 6, and 7 survey double layers, synchrotron radiation, and energy transport in plasmas, respectively. Chapter 8 covers the particle-in-cell simulation of astrophysical plasmas. Found throughout the book are examples that apply the material of the chapter or section to specific problems.

At the end of the book are appendixes highlighting topics that are often not covered in plasma physics or in astrophysics texts, or else are well-documented to the point that a short condensation suffices. Appendix A covers transmission line concepts in space plasmas. Appendix B is a condensation of the polarization properties of plasma waves. In Appendix C dusty and grain plasmas are discussed.

A list of references is given for each chapter. These are divided into parts: General references give a list of papers and books that cover the general aspects and that often give a more thorough treatment of the subjects covered, and special or specialized references document the sources for specific topics.

As far as possible, the equations are written to conform to SI regulations, but since this book deals with the plasma universe whose elements transcend many disciplines, from laboratory controlled fusion experiments to cosmology, a multitude of non-SI units are used. For example, it is customary in the laboratory to state densities in particles per cubic centimeter and magnetic induction in gauss, rather than in particles per cubic meter and tesla, as used in space plasmas. Likewise, units of light-years and parsecs are more meaningful to describe the dimensions of galaxies and clusters of galaxies than are meters. To aid visualization, both SI and familiar units are often given in the text.

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Los Alamos, New Mexico — Anthony L. Peratt

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