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All aspects of space plasmas in the solar system are introduced and explored in this text for senior undergraduate and graduate students. *Introduction to Space Physics* provides a broad, yet selective, treatment of the complex interactions of the ionized gases of the solar-terrestrial environment. The book includes extensive discussions of the sun and solar wind, the magnetized and unmagnetized planets, and the fundamental processes of space plasmas, including shocks, plasma waves, ULF waves, wave–particle interactions, and auroral processes. The text devotes particular attention to space-plasma observations and integrates these with phenomenological and theoretical interpretations.

Highly coordinated chapters, written by experts in their fields, combine to provide a comprehensive introduction to space physics. Based on an advanced undergraduate and graduate course presented in the Department of Earth and Space Sciences at UCLA, the text will be valuable to both students and professionals in the field.

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EDITED BY

Margaret G. Kivelson **Christopher T. Russell**
University of California, Los Angeles

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CONTRIBUTORS

D. Burgess
Astronomy Unit
Queen Mary and Westfield College
London, U.K.

H. C. Carlson, Jr.
Phillips Laboratory
Geophysics Directorate
Hanscom AFB
Bedford, MA

A. Egeland
Department of Physics
University of Oslo
Blindern, Oslo, Norway

C. K. Goertz (deceased)
Department of Physics and Astronomy
University of Iowa
Iowa City, IA

W. J. Hughes
Center for Space Physics
Boston University
Boston, MA

A. J. Hundhausen
High Altitude Observatory
National Center for Atmospheric Research
Boulder, CO

M. G. Kivelson
Department of Earth and Space Sciences and
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, CA

J. G. Luhmann
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, CA

R. L. McPherron
Department of Earth and Space Sciences and
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, CA

E. R. Priest
Mathematical and Computational Sciences Department
The University
St. Andrews, Scotland

C. T. Russell
Department of Earth and Space Sciences and
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, CA

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R. J. Strangeway
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, CA

R. J. Walker
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, CA

R. A. Wolf
Department of Space Physics and Astronomy
Rice University
Houston, TX

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PREFACE

THE IONIZED GASES of the solar-terrestrial environment interact in very complex and sometimes counterintuitive ways. Our intuition about gases is trained in situations in which collisions are important, but in most of the ionized gases in the solar system the magnetic and electric fields control the motion of the particles, with collisions and gravitational fields being less important. In an introductory text such as this it is difficult to decide where to begin to discuss these interactions. One could start with the simplest systems and then add complexity; one could order the material by spatial location, discussing the sun first and then proceeding to follow the energy flow outward past all the planets; or one could follow a chronological approach, according to the order of discovery. There is much to justify a spatial approach, because the sun is the energy source for most of the plasma we encounter, either through coupling with the solar wind or through photoionization. On the other hand, the chronological approach follows the way scientists originally learned about how the solar terrestrial environment behaves. This approach has the advantage that the earliest concepts were simple and grew gradually in complexity, but it has the disadvantage that some of the early ideas were wrong and that sometimes science progresses in convoluted ways. Thus, this approach can be quite inefficient.

In this book we shall attempt to combine the three approaches. We shall try always to reduce topics to their basics before introducing the complications. The overall ordering of the book will follow the energy flow, starting with the sun, but first, Chapter 1 will provide some historical perspective. The historical approach is interesting, and it allows us a quick overview of the entire field before becoming too involved with the details. We shall begin with ancient observations of the "northern lights," which we now refer to as the aurora borealis, or simply the aurora, and work our way up to the era of space exploration.

Chapter 2 covers the physics of the plasmas we encounter in space. In this chapter we describe some of the most basic physical processes that occur in space plasmas and the equations that govern them. In particular we introduce the magnetohydrodynamic (MHD) approximations that are so useful in describing the solar-terrestrial environment. In Chapter 3, E. R. Priest discusses both the "old" sun and the "new"

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sun. The new sun has emerged from the old sun of observational solar physics through the application of MHD treatments of solar phenomena.

In Chapter 4, A. J. Hundhausen takes us from the solar corona to the farthest reaches of the solar system, the heliopause, where the solar wind stops. D. Burgess follows this with a discussion of that ubiquitous process in space plasmas – the collisionless shock. Collisionless shocks are caused by processes on the sun, by the interaction of fast streams and slow streams in the solar wind, and by the diversion of the solar wind about the intrinsic and induced magnetospheres of all the planets.

In Chapter 6, R. J. Walker and C. T. Russell describe the interaction of the solar wind with a magnetized planet, both what happens to the planetary magnetic field and how the interaction affects the solar wind. In Chapters 7 and 8, J. G. Luhmann describes how an ionosphere is formed from a planetary atmosphere by the ionizing radiation from the sun and then how such an ionosphere creates a magnetic barrier to the solar-wind flow and an induced magnetosphere that deflects the solar wind, much as does an intrinsic planetary magnetic field.

In Chapter 9, W. J. Hughes examines the processes whereby energy is transferred to the earth's magnetosphere by the solar wind, the storage of that energy in the tail, and the eventual release of that energy into the inner magnetosphere and ionosphere in a magnetospheric substorm. In Chapter 10, R. A. Wolf describes the processes occurring in the inner magnetosphere.

Chapters 11 and 12 cover the wave processes in the magnetosphere. In Chapter 11, M. G. Kivelson discusses the phenomena known collectively as magnetic pulsations, which often involve the oscillation of an entire magnetic-field line. Chapter 12 reviews the waves that occur at higher frequencies, principally interacting with the energetic electrons in the magnetosphere. The majority of the material in this chapter was prepared by C. K. Goertz, who was killed in a most unfortunate incident before completion of this work. We are most grateful to R. J. Strangeway who took over the writing of the chapter.

Chapter 13, by R. L. McPherron, deals with magnetospheric dynamics and geomagnetic activity and the current systems responsible for this behavior.

In Chapter 14, H. C. Carlson, Jr., and A. Egeland cover the auroral ionosphere, where much of the energy transferred to the magnetosphere from the solar wind is ultimately deposited. Chapter 15 covers the magnetospheres of the outer planets. The book closes with a set of useful appendices covering various topics of practical importance, such as vector operations and coordinate transformations.

It is our intention in this book to provide an introduction to space physics for the beginning graduate student. Nevertheless, much of the material is suitable for upper-division undergraduates and has been tested on both undergraduates and graduate students in our Department

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of Earth and Space Sciences at the University of California, Los Angeles (UCLA).

The assembling of this book began with the convening of a "Rubey Colloquium" in March 1990. The Department of Earth and Space Sciences at UCLA holds such a colloquium annually in honor of the late W. W. Rubey (1898–1974), a career geologist with the U.S. Geological Survey and a professor of geology and geophysics at UCLA. That colloquium brought together the authors of this book, who presented lectures associated with each of the chapters over the course of a week between the winter and spring quarters. Initial drafts of the chapters were distributed at that time. Since then they have been refined and edited in an attempt to produce a more uniform style, to eliminate unnecessary duplication of material, and to fill in some of the gaps in coverage. We are particularly grateful to the Department of Earth and Space Sciences for providing the funding to initiate this project and to the National Aeronautics and Space Administration for sustaining it through their Space Grant University program administered by the California Space Institute. We are also most grateful to A. McKnight, Linda Kim, and Rose Silva, who provided clerical assistance for this project, and to UCLA students M. Ginskey, T. Meseroll, T. Mulligan, and J. Newbury, who helped to proofread the volume.

C. T. Russell
M. G. Kivelson

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