

Preface

One more textbook on plasma physics? Indeed, there are a number of excellent textbooks on the market, like the incomparable book *Introduction to Plasma Physics and Controlled Fusion* by Francis F. Chen. It is impossible to compete with a book of this clarity, or some of the other texts which have been around for longer or shorter. However, we found most of the books not well-suited for a course on space plasma physics. Some are directed more toward the interests of laboratory plasma physics, like Chen's book, others are highly mathematical, such that it would have required an additional course in applied mathematics to make them accessible to the students. The vast majority of books in the field of space plasma physics, however, are collections of review articles, like the recent *Introduction to Space Physics* edited by Margaret G. Kivelson and Christopher T. Russell. These books require that the reader already has quite some knowledge of the field.

The only textbook specifically addressed to the needs of space plasma physics is *Physics of Space Plasmas* by George K. Parks. This book covers many aspects of space plasma physics, but is ordered in terms of phenomena rather than with respect to plasma theory. To give the students a feeling for the coherency of our field, we felt the need to find a compromise between classical plasma physics textbooks and the books by Parks and Kivelson & Russell. We tried to achieve this goal during a third-year space plasma physics course, which we gave regularly at the University of Munich since 1988 for undergraduate and graduate students of geophysics, who had an average knowledge of fluid dynamics and electromagnetism.

This textbook collects and expands lecture notes from these two-semester courses. However, the first part can also be used for a one-semester undergraduate course and research scientists may find the later chapters of the second part helpful. The book is written in a self-contained way and most of the material is presented including the basic steps of derivation so that the reader can follow without need to consult original sources. Some of the more involved mathematical derivations are given in the Appendix. Special emphasis has been placed on providing instructive figures. Figures containing original measurements are scarce and have mostly been redrawn in a more schematic way.

The first five chapters provide an introduction into space physics, based on a mixture of simple theory and a description of the wealth of space plasma phenomena. A

concise description of the Earth's plasma environment is followed by a derivation of single particle motion in electromagnetic fields, adiabatic invariants, and applications to the Earth's magnetosphere and ring current. Then the origin and effects of collisions and conductivities and the formation of the ionosphere are discussed. Ohm's law and the frozen-in concept are introduced on a somewhat heuristic basis. The first part ends with an introduction into magnetospheric dynamics, including convection electric fields, current systems, substorms, and other macroscopic aspects of solar wind-magnetosphere and magnetosphere-ionosphere coupling.

The second part of the book presents a more rigorous theoretical foundation of space plasma physics, yet still contains many applications to space physics. It starts from kinetic theory, which is built on the Klimontovich approach. Introducing moments of the distribution function allows the derivation of the single and multi-fluid equations, followed by a discussion of fluid boundaries and shocks, with the Earth's magnetopause and bow shock as examples. Both, fluid and kinetic theory are then applied to derive the relevant wave modes in a plasma, again with applications from space physics.

The material presented in the present book is extended in *Advanced Space Plasma Physics*, written by the same authors. This companion textbook gives a representative selection of the many macro- and microinstabilities in a plasma, from the Rayleigh-Taylor and Kelvin-Helmholtz to the electrostatic and electromagnetic instabilities, and a comprehensive overview on the nonlinear aspects relevant for space plasma physics, e.g., wave-particle interaction, solitons, and anomalous transport.

We are grateful to Rosmarie Mayr-Ihbe for turning our often rough sketches into the figures contained in this book. It is also a pleasure to thank Jim LaBelle for valuable contributions, Anja Czaykowska and Thomas Bauer for careful reading of the manuscript and many suggestions, and Karl-Heinz Mühlhäuser and Patrick Daly for helping us with \LaTeX . We gratefully acknowledge the support of Heinrich Soffel, Gerhard Haerendel and Gregor Morfill, and acknowledge the patience of our colleagues at MPE, when we worked on this book instead of finishing other projects in time. Both of us owe deep respect to our teachers who introduced us into geophysics, Jürgen Untiedt and the late Gerhard Fanselau.

Last but not least, we would like to mention that we have profited from many books and reviews on plasma and space physics. References to most of them have been included into the suggestions for further reading at the ends of the chapters. These suggestions, however, do not include the very large number of original papers, which we made use of and are indebted to.

Needless to say, we have made all efforts to make the text error-free. However, this is an unsurmountable task. We hope that the readers of this book will kindly inform us about misprints and errors they may find in here, preferentially by electronic mail to bj@mpe-garching.mpg.de. We will be grateful for any hints and post them with other errors on <http://www.mpe-garching.mpg.de/bj/bspp.html>.