Preface

This book is the second volume of our introductory text on Space Plasma Physics. The first volume is published under the title *Basic Space Plasma Physics* and covers the more fundamental aspects, i.e., single particle dynamics, fluid equilibria, and waves in space plasmas. This second volume extends the material to the more advanced fields of plasma instabilities and nonlinear effects.

Actually, there are already a number of monographs, where the general nonlinear plasma methods are described in considerable detail. But many of these books are quite specialized. The present book selects those methods, which are applied in space plasma physics, and, on the expense of detailedness, tries to make them accessible to the more practically oriented student and researcher by putting the new achievements and methods into the context of general space physics.

The first part of the book is concerned with the evolution of linear instabilities in plasmas. Instabilities have turned out to be the most interesting and important phenomena in physics. They arise when free energy has accumulated in a system which the system wants to get rid of. In plasma physics there is a multitude of reasons for the excitation of instabilities. Inhomogeneities may evolve both in real space and in velocity space. These inhomogeneities lead to the generation of instabilities as a first linear and straightforward reaction of the plasma to such deviations from thermal equilibrium. The first chapters cover a representative selection of the many possible macro- and microinstabilities in space plasmas, from the Rayleigh-Taylor and Kelvin-Helmholtz to electrostatic and electromagnetic kinetic instabilities. Their quasilinear stabilization and nonlinear evolution and their application to space physics problems is treated.

As a natural extension of the linear evolution, nonlinear effects do inevitably evolve in an unstable plasma, simply because an instability cannot persist forever but will exhaust the available free energy. Therefore all instabilities are followed by nonlinear evolution. The second part of the book, the chapters on nonlinear effects, can only give an overview about the vast field of nonlinearities. These chapters include the nonlinear evolution of single waves, weak turbulence, and strong turbulence, all presented from the view-point of their relevance for space plasma physics. Special topics include soliton formation, caviton collapse, anomalous transport, auroral particle acceleration, and elements of the theory of collisionless shocks.

Linear theory occupies about half of the book. The second half reviews nonlinear theory as systematically as possible, given the restricted space. The last chapter presents a number of applications. The reader may find our selection a bit unsystematic, but we have chosen to select only those which, in our opinion, demonstrate the currently more important aspects of space physics. There are many other small effects which need to be treated using nonlinear theory, but have been neglected here, since we did not find them fundamental enough to be included in a textbook like the present one. Nevertheless, we hope that the reader will find the book useful as a guide to unstable and nonlinear space plasma physics, giving him a taste of the complexity of the problems.

Since space plasma physics has in the past served as a reservoir of ideas and tools also for astrophysics, the present volume will certainly be useful for the needs of a course in non-relativistic plasma astrophysics and for scientists working in this field. With a slight extension to the parameter ranges of astrophysical objects most of the instabilities and nonlinear effects do also apply to astrophysics, as long as high-energy effects and relativistic temperatures are not important.

It is a pleasure to thank Rosmarie Mayr-Ihbe for turning our often rough sketches into the figures contained in this book and Thomas Bauer, Anja Czaykowska, Thomas Leutschacher, Reiner Lottermoser, and especially Joachim Vogt for carefully reading the manuscript. We gratefully acknowledge the continuous support of Gerhard Haerendel, Gregor Morfill and Heinrich Soffel.

Last 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 end of each chapter. These suggestions, however, do not include the large number of original papers, which we made use of and are indebted to.

We have made every effort to keep the text error-free; unfortunately this is a never ending task. We hope that the readers will kindly inform us about misprints and errors, preferentially by electronic mail to *bj@mpe-garching.mpg.de*. We will be grateful for any hints and post them on *http://www.mpe-garching.mpg.de/bj/aspp.html*.