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Kinetic Theory of the Inner Magnetospheric Plasma

Springer

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To the loving memory of my parents
Vladimir and Polina Khazanov
To my wife, Tamara, and my sons
Igor and Max

Preface

The inner magnetosphere is an important region of space plasma because it is one of the "kitchens" for space weather effects. The scientific understanding of this region is important for predicting the interaction between space environmental conditions and human activities.

The inner magnetospheric plasma is a unique composition of different plasma particles and waves. It covers a huge plasma energy range with spatial and time variations of many orders of magnitude. In such a situation, the kinetic approach is the key element, and must be the starting point of a proper theoretical description of these inner magnetospheric plasma phenomena; a book dedicated to this particular area of research is required.

The kinetic theory of the inner magnetosphere has many different aspects and could not be described in one book. This particular book is based on my research and Space Plasma Physics and Advance Plasma Physics courses that I have delivered at different universities of the United States and Russia. The major topics in this book are: Kinetic Theory of Superthermal Electrons, Kinetic Foundation of the Hydrodynamic Description of Space Plasmas (including wave–particle interaction processes), and Kinetic Theory of the Terrestrial Ring Current.

The analytical solutions of simplified transport equations are the distinguishable features of this book. Approximate analytic solutions of transport phenomena are very useful because they help us gain physical insight into how the system responds to varying sources of mass, momentum, and energy and also to various external boundary conditions. They also provide us a convenient method to test the validity of complicated numerical models, a task that is usually tedious and time consuming.

This book provides a broad introduction to the theory of space plasma physics for students who intend to carry out independent research in upper atmospheric science and space physics. It is designed to provide a comprehensive description of the different kinds of transport equations for both plasma particles and waves with an emphasis on the applicability and limitations of each set of equations. It is hoped that this book will provide students and space researchers with an understanding of how to determine the best approach to any upper atmospheric or space physics problem.

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Greenbelt, MD
September 2009

George V. Khazanov

Biographical Sketch

Dr. George V. Khazanov is a senior scientist in the Heliosphysics Science Division at the NASA Goddard Space Flight Center. Prior to joining NASA, he was a Tenured Professor of Physics at the University of Alaska Fairbanks. Dr. Khazanov has extensive experience in space plasma physics and simulation of geophysical plasmas. His specific research areas include: space plasma energization and transport, kinetic theory of superthermal electrons in the ionosphere and plasmasphere, hydrodynamic and kinetic theory of space plasma in the presence of wave activity, theoretical and numerical-modeling investigations of ionosphere-plasmasphere interactions, theoretical studies of the artificial injection of charged and neutral particles into the ionosphere, and wave and beam-induced plasma instabilities in the ionosphere and magnetosphere. Dr. Khazanov was the Dean of the College of Physics, and the Theoretical Physics Department Chair at Altai State University, Russia; Director of the Ionospheric Plasma Physics Laboratory at Irkutsk State University, Russia. He supervised and directed more than 30 M.S. and 15 Ph.D. graduates. He is the author or coauthor of 6 books and about 250 peer reviewed publications.

Book Summary

This book provides a broad introduction to the kinetic theory of space plasma physics with the major focus on the inner magnetospheric plasma. It is designed to provide a comprehensive description of the different kinds of transport equations for both plasma particles and waves with an emphasis on the applicability and limitations of each set of equations. The major topics are: Kinetic Theory of Superthermal Electrons, Kinetic Foundation of the Hydrodynamic Description of Space Plasmas (including wave-particle interaction processes), and Kinetic Theory of the Terrestrial Ring Current. Distinguishable features of this book are the analytical solutions of simplified transport equations. Approximate analytic solutions of transport phenomena are very useful because they help us gain physical insight into how the system responds to varying sources of mass, momentum and energy and also to various external boundary conditions. They also provide us a convenient method to test the validity of complicated numerical models, a task that is usually tedious and time consuming. It is hoped that this book will provide students and space researchers with an understanding of how to determine the best approach to any upper atmospheric or space physics problem.

Contents

Abbreviations

AMIE	Assimilative Mapping of Ionospheric Electrodynamics
AMPTE	Active Magnetospheric Particle Tracer Explorers
AMPTE/CCE	Active Magnetospheric Particle Tracer Explorers/Charge Composition Explorer
BGK	Bhatnagar-Gross-Krook
CGL	Chew-Goldberger-Low
CPCP	Cross Polar Cap Potential
CRRES	Combined Release and Radiation Effects Satellite
DE	Dynamics Explorer
DMSP	Defense Meteorological Satellites Program
ELF	Extremely Low Frequency
EMIC-waves	ElectroMagnetic Ion Cyclotron waves
EUV	Extreme UltraViolet
FAC	Field-Aligned Current
FFT	Fast Fourier Transform
FLIP	Field Line Interhemispheric Plasma
FMS	Fast MagnetoSonic
FWHM	Full Width at Half Maximum
GPS	Global Positioning System
HENA	High-Energy Neutral Atom
ICME	Interplanetary Coronal Mass Ejection
IM/S	Inner Magnetosphere/Storm
IMAGE	Imager for Magnetopause-to-Aurora Global Exploration
IMF	Interplanetary Magnetic Field
IRI	International Reference Ionosphere
IRM	Ion Release Module
ISEE	International Sun–Earth Explorer
ISIS	International Satellites for Ionospheric Studies
LANL	Los Alamos National Lab
LCB	Loss Cone Boundary

LFW	Low-Frequency Waves
LHR	Lower-Hybrid Resonance
LHW	Lower-Hybrid Waves
LINAC	LINear Accelerator
MENA	Medium-Energy Neutral Atom
MHD equations	MagnetoHydroDynamic equations
MLT	Magnetic Local Time
MSIS	90-Atmosphere Model
PE	PhotoElectron
PIC	Particle-In-Cell
PSE	Plasma Sheet Electron
PT	Plasma Turbulence
PTE	Plasma Transfer Event
RB	Radiation Belt
RC	Ring Current
RIS	Radio wave Incoherent Scatter
RPI	Radio Plasma Imager
SAPS	SubAuroral Polarization Stream
SAR	Stable Auroral Red
UKS	United Kingdom Subsatellite
VHF	Very High Frequency
VLF	Very Low Frequency