Computational Methods For Astrophysical Fluid Flow Saas Fee Advanced Course 27 Lecture Notes 1997 Swiss Society For Astrophysics And Astronomy Saas Fee Advanced Courses 1998 Edition By Leveque Randall J Mihalas Dimitri Dorfi Ea Mi 1 2 Ller 199

Written as both a textbook and a handy reference, this text deliberately avoids complex mathematics assuming only basic familiarity with geodynamic theory and calculus. Here, the authors have brought together the key numerical techniques for geodynamic modeling, demonstrations of how to solve problems including lithospheric deformation, mantle convection and the geodynamo. Building from a discussion of the fundamental principles of mathematical and numerical modeling, the text moves into critical examinations of each of the different techniques before concluding with a detailed analysis of specific geodynamic applications. Key differences between methods and their respective limitations are also discussed - showing readers when and how to apply a particular method in order to produce the most accurate results. This is an essential text for advanced courses on numerical and computational modeling in geodynamics and geophysics, and an invaluable resource for researchers looking to master cutting-edge techniques. Links to supplementary computer codes are available online.

This book contains review articles of most of the topics addressed at the conf- ence on Simulations of Magnetohydrodynamic turbulence in astrophysics: recent achievements and perspectives which took place from July 2 to 6, 2001 at the Institut Henri Poincar ?e in Paris. We made the choice to publish these lectures in a tutorial form so that they can be read by a broad audience. As a result, this book does not give an exhaustive view of all the subjects addressed during the conference. The main objective of this workshop which gathered about 90 scientists from di?erent ?elds, was to present and confront recent results on the topic of t- bulence in magnetized astrophysical environments. A second objective was to discuss the latest generation of numerical codes, such as those using adaptive mesh re?nement (AMR) techniques. During a plenary discussion at the end of the workshop discussions were held on several topics, often at the heart of vivid controversies. Topics included the timescale for the dissipation of magneto-hydrodynamical (MHD) turbulence, the role of boundary conditions, the characteristics of imbalanced turbulence, the validity of the polytropic approach to Alfv ?en waves support within interst- lar clouds, the source of turbulence inside clouds devoid of stellar activity, the timescale for star formation, the Alfv ?en Mach number of interstellar gas motions, the formation process for helical ?elds in the interstellar medium. The impact of small upon large scales was also discussed.

The book begins with a historical introduction, "Star Formation: The Early History", that presents new material of interest for students and historians of science. This is followed by two long articles on "Pre-Main-Sequence Evolution of Stars and Young Clusters" and "Observations of Young Stellar Objects". These articles on the fascinating problem of star formation from interstellar matter give a thorough overview of present-day theories and observations. The articles contain material so far unpublished in the astronomical literature. The book addresses graduate students and can be used as a textbook for advanced courses in stellar astrophysics.

In 1975 the Marcel Grossmann Meetings were established by Remo Ruffini and Abdus Salam to provide a forum for discussion of recent advances in gravitation, general relativity, and relativistic field theories. In these meetings, which are held once every three years, every aspect of research is emphasized - mathematical foundations, physical predictions, and numerical and experimental investigations. The major objective of these meetings is to facilitate exchange among scientists, so as to deepen our understanding of the structure of space-time and to review the status of both the ground-based and the space-based experiments aimed at testing the theory of gravitation.The Marcel Grossmann Meetings have grown under the guidance of an International Organizing Committee and a large International Coordinating Committee. The first two meetings, MG1 and MG2, were held in Trieste (1975, 1979). A most memorable MG3 (1982) was held in Shanghai and represented the first truly international scientific meeting in China after the so-called Cultural Revolution. Three years later MG4 was held in Rome (1985). It was at MG4 that ';astroparticle physics'; was born.MGIXMM was organized by the International Organizing Committee composed of D Blair, Y Choquet-Bruhat, D Christodoulou, T Damour, J Ehlers, F Everitt, Fang Li Zhi, S Hawking, Y Ne'eman, R Ruffini (chair), H Sato, R Sunyaev, and S Weinberg. Essential to the organization was an International Coordinating Committee of 135 members from scientific institutions of 54 countries. MGIXMM was attended by 997 scientists of 69 nationalities. It took place on 2-8 July 2000 at the University of Rome, Italy. The scientific programs included 60 plenary and review talks, as well as talks in 88 parallel sessions. The three volumes of the proceedings of MGIXMM present a rather authoritative view of relativistic astrophysics, which is becoming one of the priorities in scientific endeavour. The papers appearing in these volumes cover all aspects of gravitation, from mathematical issues to recent observations and experiments. Their intention is to give a complete picture of our current understanding of gravitational theory at the turn of the millennium.The Marcel Grossmann Individual Awards for this meeting were presented to Cecille and Bryce DeWitt, Riccardo Giacconi and Roger Penrose, while the Institutional Award went to the Solvay Institute, accepted on behalf of the Institute by Jacques Solvay and Ilya Prigogine. The acceptance speeches are also included in the proceedings.

Publisher Description

This book is the first of several volumes on solids in the Shock Wave Science and Technology Reference Library. This is a unique collection, and the library as a whole sets out to comprehensively and authoritatively cover and review at research level the subject matter with all its ramifications. All the chapters are self-contained and can be read independently of each other, though they are of course thematically interrelated.

After centuries of research, turbulence in fluids is still an unsolved problem. The graduate-level lectures in this volume cover the state of the art of numerical methods for fluid mechanics. The research in this collection covers wavelet-based methods, the semi-Lagrangian method, the Lagrangian multi-pole method, continuous adaptation of curvilinear grids, finite volume methods, shock-capturing methods, and ENO schemes. The most recent research on large eddy simulations and Reynolds stress modeling is presented in a way that is accessible to engineers, postdoctoral researchers, and graduate students. Applications cover industrial flows, aerodynamics, two-phase flows, astrophysical flows, and meteorology. This volume would be suitable as a textbook for graduate students with a background in fluid mechanics.

This book summarizes and highlights progress in Dynamical Systems achieved during six years of the German Priority Research

Program "Ergotic Theory, Analysis, and Efficient Simulation of Dynamical Systems", funded by the Deutsche Forschungsgemeinschaft (DFG). The three fundamental topics of large time behavior, dimension, and measure are tackled with by a rich circle of uncompromisingly rigorous mathematical concepts. The range of applied issues comprises such diverse areas as crystallization and dendrite growth, the dynamo effect, efficient simulation of biomolecules, fluid dynamics and reacting flows, mechanical problems involving friction, population biology, the spread of infectious diseases, and quantum chaos. The surveys in the book are addressed to experts and non-experts in the mathematical community alike. In addition they intend to convey the significance of the results for applications fair into the neighboring disciplines of Science.

The study of the Solar system, particularly of its newly discovered outer parts, is one of the hottest topics in modern astrophysics with great potential for revealing fundamental clues about the origin of planets and even the emergence of life. The three lecturers of the 35th Saas-Fee Advanced Course, which have been updated and collected in this volume, cover the field from observational, theoretical and numerical perspectives.

Star clusters are at the heart of astronomy, being key objects for our understanding of stellar evolution and galactic structure. Observations with the Hubble Space Telescope and other modern equipment have revealed fascinating new facts about these galactic building blocks. This book provides two comprehensive and up-to-date, pedagogically designed reviews on star clusters by two well-known experts in the field. Bruce Carney presents our current knowledge of the relative and absolute ages of globular clusters and the chemical history of our Galaxy. Bill Harris addresses globular clusters in external galaxies and their use as tracers of galaxy formation and cosmic distance indicators. The book is written for graduate students as well as professionals in astronomy and astrophysics.

After three decades of intense research in X-ray and gamma-ray astronomy, the time was ripe to summarize basic knowledge on X-ray and gamma-ray spectroscopy for interested students and researchers ready to become involved in new high-energy missions. This volume exposes both the scientific basics and modern methods of high-energy spectroscopic astrophysics. The emphasis is on physical principles and observing methods rather than a discussion of particular classes of high-energy objects, but many examples and new results are included in the three chapters as well.

Astrophysics of GaseousNebulae and Active GalacticNuclei, second edition, is a graduate-level text and reference book on gaseous nebulae, nova and supernova remnants. It will bevaluable to anyone seriously interested in astrophysics.

This is the 2nd edition of the book, Flow Visualization: Techniques and Examples, which was published by Imperial College Press in 2000. Many of the chapters have been revised and updated to take into consideration recent changes in a number of flow visualization and measurement techniques, including an updated high quality flow gallery. Unique among similar publications, this book focuses on the practical rather than theoretical aspects. Obtaining high quality flow visualization results is, in many ways, more of an art than a science, and experience plays a key deciding role. The depth and breadth of the material will make this book invaluable to readers of all levels of experience in the field. Sample Chapter(s) Chapter 1: Interpretation of Flow Visualization (4,633 KB) Chapter 2: Hydrogen Bubble Visualization (15,745 KB) Contents:Interpretation of Flow VisualizationHydrogen Bubble VisualizationDye and Smoke VisualizationMolecular Tagging Velocimetry and ThermometryPlanar Imaging of Gas Phase FlowsDigital Particle Image VelocimetrySurface Temperature Sensing with Thermochromic Liquid CrystalsPressure and Shear Sensitive CoatingsMethods for Compressible FlowsThree-Dimensional ImagingQuantitative Flow Visualization via Fully Resolved Four-Dimensional ImagingVisualization, Feature Extraction, and Quantification of Numerical Visualizations of High-Gradient Compressible FlowsColor Plates and Flow Gallery Readership: Undergraduate and graduate students as well as researchers in flow visualization. Keywords:Dye and Smoke Visualization;Hydrogen Bubble;Qualitative and Quantitative Flow Visualization;Digital Particle Image Velocimetry;Molecular Tagging Velocimetry;Laser ImagingKey Features:Each chapter of the book is written by an expert (or experts) in the fieldThe book includes a flow gallery of high quality flow visualization imagesThe depth and breadth of the material will make it invaluable to readers of all levels of experience in flow visualizationReviews: “The book combines a broad overview with a deep insight into the field of flow visualization. The pros and cons of each method and pitfalls in the interpretation of measurements results are discussed. Many practical tips are given. The book is very useful for students and researchers. It is highly recommended.” ZAMM Journal

Unique reference for graduate students and researchers addressing common problems and methods in studying galaxy, star and planet formation.

The physics of plasmas is an extremely rich and complex subject as the variety of topics addressed in this book demonstrates. This richness and complexity demands new and powerful techniques for investigating plasma physics. An outgrowth from his graduate course teaching, now with corrections, Tajima's text provides not only a lucid introduction to computational plasma physics, but also offers the reader many examples of the way numerical modeling, properly handled, can provide valuable physical understanding of the nonlinear aspects so often encountered in both laboratory and astrophysical plasmas. Included here are computational methods for modern nonlinear physics as applied to hydrodynamic turbulence, solitons, fast reconnection of magnetic fields, anomalous transports, dynamics of the sun, and more. The text contains examples of problems now solved using computational techniques including those concerning finite-size particles, spectral techniques, implicit differencing, gyrokinetic approaches, and particle simulation.

This book is planned to publish with an objective to provide a state-of-art reference book in the area of computational fluid dynamics for CFD engineers, scientists, applied physicists and post-graduate students. Also the aim of the book is the continuous and timely dissemination of new and innovative CFD research and developments. This reference book is a collection of 14 chapters characterized in 4 parts: modern principles of CFD, CFD in physics, industrial and in castle. This book provides a comprehensive overview of the computational experiment technology, numerical simulation of the hydrodynamics and heat transfer processes in a two dimensional gas, application of lattice Boltzmann method in heat transfer and fluid flow, etc. Several interesting applications area are also discusses in the book like underwater vehicle propeller, the flow behavior in gas-cooled nuclear reactors, simulation odour dispersion around windbreaks and so on.

This edited review book on Godunov methods contains 97 articles, all of which were presented at the international conference on Godunov Methods: Theory and Applications, held at Oxford in October 1999, to commemo rate the 70th birthday of the Russian mathematician Sergei K. Godunov. The meeting enjoyed the participation of 140 scientists from 20 countries; one of the participants commented: everyone is here, meaning that virtu ally everybody who had made a

significant contribution to the general area of numerical methods for hyperbolic conservation laws, along the lines first proposed by Godunov in the fifties, was present at the meeting. Sadly, there were important absentees, who due to personal circumstance could not at tend this very exciting gathering. The central theme o{ the meeting, and of this book, was numerical methods for hyperbolic conservation laws fol lowing Godunov's key ideas contained in his celebrated paper of 1959. But Godunov's contributions to science are not restricted to Godunov's method.

Written by experts from geophysics, astrophysics and engineering, this unique book on the interdisciplinary aspects of turbulence offers recent advances in the field and covers everything from the very nature of turbulence to some practical applications.

The Eighth International Conference on Hyperbolic Problems - Theory, Nu merics, Applications, was held in Magdeburg, Germany, from February 27 to March 3, 2000. It was attended by over 220 participants from many European countries as well as Brazil, Canada, China, Georgia, India, Israel, Japan, Taiwan, und the USA. There were 12 plenary lectures, 22 further invited talks, and around 150 con tributed talks in parallel sessions as well as posters. The speakers in the parallel sessions were invited to provide a poster in order to enhance the dissemination of information. Hyperbolic partial differential equations describe phenomena of material or wave transport in physics, biology and engineering, especially in the field of fluid mechanics. Despite considerable progress, the mathematical theory is still strug gling with fundamental open problems concerning systems of such equations in multiple space dimensions. For various applications the development of accurate and efficient numerical schemes for computation is of fundamental importance. Applications touched in these proceedings concern one-phase and multiphase fluid flow, phase transitions, shallow water dynamics, elasticity, extended ther modynamics, electromagnetism, classical and relativistic magnetohydrodynamics, cosmology. Contributions to the abstract theory of hyperbolic systems deal with viscous and relaxation approximations, front tracking and wellposedness, stability ofshock profiles and multi-shock patterns, traveling fronts for transport equations. Numerically oriented articles study finite difference, finite volume, and finite ele ment schemes, adaptive, multiresolution, and artificial dissipation methods.

Numerical Methods in Astrophysics: An Introduction outlines various fundamental numerical methods that can solve gravitational dynamics, hydrodynamics, and radiation transport equations. This resource indicates which methods are most suitable for particular problems, demonstrates what the accuracy requirements are in numerical simulations, a

Astrophysical dynamos are at the heart of cosmic magnetic fields of a wide range of scales, from planets and stars to entire galaxies. This book presents a thorough, step-by-step introduction to solar and stellar dynamos. Looking first at the ultimate origin of cosmic seed magnetic fields, the antagonists of field amplification are next considered: resistive decay, flux expulsion, and flows ruled out by anti-dynamo theorems. Two kinematic flows that can act as dynamos are then studied: the Roberts cell and the CP-flow. Mean-field electrodynamics and derivation of the mean-field dynamo equations lead to the alpha Omega-dynamo, the flux transport dynamo, and dynamos based on the Babcock-Leighton mechanism. Alternatives to the mean-field theory are also presented, as are global MHD dynamo simulations. Fluctuations and grand minima in the solar cycle are discussed in terms of dynamo modulations through stochastic forcing and nonlinear effects. The book concludes with an overview of the major challenges in understanding stellar magnetic fields and their evolution in terms of various dynamo models, global MHD simulations, and fossil fields. Each chapter is accompanied by an annotated bibliography, guiding the readers to the relevant technical literature, which may lead them to carry out their own research in the field of dynamo theory.

Stellar pulsations provide a complex system in stars. This complexity is studied by analyzing the non-sinusoidal, semi-regular, or irregular light curves. This unique volume summarizes the application of recent theoretical results obtained from stellar pulsation studies. In addition, the latest developments in hydrodynamic simulations are discussed. A historical sketch of the study of beat Cepheids, first known for their variable amplitudes, is given as an introduction to the book. This introduction clearly demonstrates how complicated the study of variable stars can be, and therefore challenges and invites the reader to study the entire book.

This book surveys analytical and numerical techniques appropriate to the description of fluid motion with an emphasis on the most widely used techniques exhibiting the best performance.Analytical and numerical solutions to hyperbolic systems of wave equations are the primary focus of the book. In addition, many interesting wave phenomena in fluids are considered using examples such as acoustic waves, the emission of air pollutants, magnetohydrodynamic waves in the solar corona, solar wind interaction with the planet venus, and ion-acoustic solitons.

Nonlinear dynamo theory is central to understanding the magnetic structures of planets, stars and galaxies. In chapters contributed by some of the leading scientists in the field, this text explores some of the recent advances in the field. Both kinetic and dynamic approaches to the subject are considered, including fast dynamos, topological methods in dynamo theory, physics of the solar cycle and the fundamentals of mean field dynamo. Advances in Nonlinear Dynamos is ideal for graduate students and researchers in theoretical astrophysics and applied mathematics, particularly those interested in cosmic magnetism and related topics, such as turbulence, convection, and more general nonlinear physics.

Computational Methods for Astrophysical Fluid FlowSaas-Fee Advanced Course 27. Lecture Notes 1997 Swiss Society for Astrophysics and AstronomySpringer Science & Business Media

The research scenario in advanced systems for protecting critical infrastructures and for deeply networked information tools highlights a growing link between security issues and the need for intelligent processing abilities in the area of information s- tems. To face the ever-evolving nature of cyber-threats, monitoring systems must have adaptive capabilities for continuous adjustment and timely, effective response to modifications in the environment. Moreover, the risks of improper access pose the need for advanced identification methods, including protocols to enforce comput-security policies and biometry-related technologies for physical authentication. C- putational Intelligence methods offer a

wide variety of approaches that can be fruitful in those areas, and can play a crucial role in the adaptive process by their ability to learn empirically and adapt a system's behaviour accordingly. The International Workshop on Computational Intelligence for Security in Inf- mation Systems (CISIS) proposes a meeting ground to the various communities - volved in building intelligent systems for security, namely: information security, data mining, adaptive learning methods and soft computing among others. The main goal is to allow experts and researchers to assess the benefits of learning methods in the data-mining area for information-security applications. The Workshop offers the opportunity to interact with the leading industries actively involved in the critical area of security, and have a picture of the current solutions adopted in practical domains. This volume of Advances in Soft Computing contains accepted papers presented at CISIS'08, which was held in Genova, Italy, on October 23rd–24th, 2008.

One of the major achievements in computational fluid dynamics has been the development of numerical methods for simulating compressible flows, combining higher-order accuracy in smooth regions with a sharp, oscillation-free representation of embedded shocks methods and now known as "high-resolution schemes". Together with introductions from the editors written from the modern vantage point this volume collects in one place many of the most significant papers in the development of high-resolution schemes as occured at ICASE.

This book provides a lively and approachable introduction to the main concepts and techniques of relativistic hydrodynamics in a form that will appeal to physicists at advanced undergraduate and post-graduate levels. The book is divided in three parts. The first part deals with the physical aspects of relativistic hydrodynamics, touching fundamental topics such as kinetic theory, equations of state, linear and nonlinear waves in fluids, and the treatment ofnon-ideal fluids. The second part provides an introductory but complete description of those numerical methods currently adopted in the solution of the relativistic hydrodynamic equations. Finally, the thirdpart is devoted to applications and considers several physical and astrophysical systems for which relativistic hydrodynamics plays a crucial role. The book is especially recommended to astrophysicists, particle physicists, and applied mathematicians.

"Computational Fluid Dynamics Based on the Unified Coordinates" reviews the relative advantages and drawbacks of Eulerian and Lagrangian coordinates as well as the Arbitrary Lagrangian-Eulerian (ALE) and various moving mesh methods in Computational Fluid Dynamics (CFD) for one- and multi-dimensional flows. It then systematically introduces the unified coordinate approach to CFD, illustrated with numerous examples and comparisons to clarify its relation with existing approaches. The book is intended for researchers, graduate students and practitioners in the field of Computational Fluid Dynamics. Emeritus Professor Wai-Hou Hui and Professor Kun Xu both work at the Department of Mathematics of the Hong Kong University of Science & Technology, Hong Kong, China.

This book lays the foundations of gas- and fluid dynamics.The basic equations are developed from first principles, building on the (assumed) knowledge of Classical Mechanics. This leads to the discussion of the mathematical properties of flows, conservation laws, perturbation analysis, waves and shocks. Most of the discussion centers on ideal (frictionless) fluids and gases. Viscous flows are discussed when considering flows around obstacles and shocks. Many of the examples used to illustrate various processes come from astrophysics and geophysical phenomena.

This collection of 7 lectures is intended to be a textbook for graduate students who want to learn about modern developments in astronomy and astrophysics. The first part surveys various aspects of the late stages of stellar evolution, including observation and theory. B.C. de Loore's long article on stellar structure is followed by reviews on supernovae, on circumstellar envelopes, and on the evolution of binaries. The second part deals with the important problem of modeling stellar evolution based on the computational hydrodynamics.

Black Holes are still considered to be among the most mysterious and fascinating objects in our universe. Awaiting the era of gravitational astronomy, much progress in theoretical modeling and understanding of classical and quantum black holes has already been achieved. The present volume serves as a tutorial, high-level guided tour through the black-hole landscape: information paradox and blackhole thermodynamics, numerical simulations of black-hole formation and collisions, braneworld scenarios and stability of black holes with respect to perturbations are treated in great detail, as is their possible occurrence at the LHC. An outgrowth of a topical and tutorial summer school, this extensive set of carefully edited notes has been set up with the aim of constituting an advanced-level, multi-authored textbook which meets the needs of both postgraduate students and young researchers in the fields of modern cosmology, astrophysics and (quantum) field theory.

This book leads directly to the most modern numerical techniques for compressible fluid flow, with special consideration given to astrophysical applications. Emphasis is put on high-resolution shock-capturing finite-volume schemes based on Riemann solvers. The applications of such schemes, in particular the PPM method, are given and include large-scale simulations of supernova explosions by core collapse and thermonuclear burning and astrophysical jets. Parts two and three treat radiation hydrodynamics. The power of adaptive (moving) grids is demonstrated with a number of stellar-physical simulations showing very crispy shock-front structures.

The underlying astrophysical mechanisms of the objects known as asymptotic giant branch stars - the structures that occur during the dramatic period prior to a star's death - is the main theme of this text. Over the past three decades, asymptotic giant branch stars have become a topic of their own, and the contributions to this volume all focus on these entities themselves, rather than their connections to other fields of astronomy. Among the many topics covered are new methods of high- quality infrared observation and the more detailed and realistic simulations made possible by increasingly fast computers. This collection should be useful to graduate students who work in the field, teachers who want to address the subject in their courses, and to astronomers from various backgrounds who are interested in the astrophysics of AGB stars.

The 34th Saas-Fee advanced course of the Swiss Society of Astronomy and Astrophysics (SSAA) took place from March

15 to 20, 2004, in Davos, on the subject of The Sun, Solar Analogs and the Climate. PresentlytheSwissmountainresortofDavosisprobablymostwellknown for hosting an event on globalization. However, it is because Davos also happens to be the seat of the Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center, that this course on a “global” subject was hosted here. Exceptionally, the topic of this course was not purely astrophysical, but themembersoftheSSAAdecidedtosupportitallthesameduetothetimely topic of global warming and its possible link to solar variations. In these times of concern about global warming, it is important to und- stand solar variability and its interaction with the atmosphere. Only in this way can we distinguish between the solar and anthropogenic contributions to the rising temperatures. Therefore, this course addressed the observed va- ability of the Sun and the present understanding of the variability’s origin and its impact on the Earth’s climate. Comparing the solar variability with that of solar analog stars leads to a better understanding of the solar activity cycle and magnetic activity in general, and helps us to estimate how large the solar variations could be on longer time scales. Inspiteofthefantasticweatherandsnowconditionswhichreignedduring this week, the participants assiduously took part in the lectures. This is proof ofthehighqualityofthelecturesthatthethreespeakers,JoannaHaigh,Mike Lockwood and David Soderblom, delivered. We deeply thank them for their contributions and e?orts and hope that the readers will enjoy the book as much as we enjoyed their lectures.

This unique and encyclopedic reference work describes the evolution of the physics of modern shock wave and detonation from the earlier and classical percussion. The history of this complex process is first reviewed in a general survey. Subsequently, the subject is treated in more detail and the book is richly illustrated in the form of a picture gallery. This book is ideal for everyone professionally interested in shock wave phenomena.

Traditionally, radiative transfer has been the domain of astrophysicists and climatologists. In nuclear technology one has been dealing with the ana- gous equations of neutron transport. In recent years, applications of radiative transferincombustionmachinedesignandinmedicinebecamemoreandmore important. In all these disciplines one uses the radiative transfer equation to model the formation of the radiation ?eld and its propagation. For slabs and spheres e?ective algorithms for the solution of the transfer equation have been ava- able for quite some time. In addition, the analysis of the equation is quite well developed. Unfortunately, in many modern applications the approximation of a 1D geometry is no longer adequate and one has to consider the full 3D dependencies. This makes the modeling immensely more intricate. The main reasons for the di?culties result from the fact that not only the dimension of the geometric space has to be increased but one also has to employ two angle variables (instead of one) and very often one has to consider frequency coupling (due to motion or redistribution in spectral lines). In actual cal- lations this leads to extremely large matrices which, in addition, are usually badly conditioned and therefore require special care. Analytical solutions are not available except for very special cases. Although radiative transfer problems are interesting also from a ma- ematical point of view, mathematicians have largely neglected the transfer equation for a long time.

An introduction to magnetohydrodynamics combining theory with advanced topics including the applications of plasma physics to thermonuclear fusion and plasma astrophysics.