

Chapter 17

Numerical Methods for Astrophysics

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ABSTRACT

The physical laws astrophysicists use to describe their phenomena are believed to have been understood in many cases. Thus modelling astrophysical phenomena is focussed on the numerical implementation of these models. The main issue astrophysicists have to overcome is the large range of spatial, temporal and density scales.

The models typically are the compressible inviscid Euler equations or magnetohydrodynamic equations in three space dimensions coupled with many source terms. The numerical methods used often are finite volume methods or particle methods. Numerical methods that deal with the large range of scales need to be addressed individually for each problem at hand. Examples of these methods are the introduction of subgrid scale models, using time implicit methods or moving mesh methods.

These notes are strongly indebted to discussions with Fritz Röpke from Heidelberg University and the Heidelberg Institute of Technological Science, <http://www.h-its.org/en/research/pso/people/>.

Numerical Astrophysics

Ian Foster, Carl Kesselman



Numerical Astrophysics:

Numerical Methods in Astrophysics Peter Bodenheimer, Gregory P. Laughlin, Michal Rozyczka, Tomasz Plewa, Harold W. Yorke, Harold W. Yorke, 2006-12-13 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 and suggests ways to test for and reduce the inevitable negative effects After an introduction to the basic equations and derivations the book focuses on practical applications of the numerical methods It explores hydrodynamic problems in one dimension N body particle dynamics smoothed particle hydrodynamics and stellar structure and evolution The authors also examine advanced techniques in grid based hydrodynamics evaluate the methods for calculating the gravitational forces in an astrophysical system and discuss specific problems in grid based methods for radiation transfer The book incorporates brief user instructions and a CD ROM of the numerical codes allowing readers to experiment with the codes to suit their own needs With numerous examples and sample problems that cover a wide range of current research topics this highly practical guide illustrates how to solve key astrophysics problems providing a clear introduction for graduate and undergraduate students as well as researchers and professionals **Numerical**

Astrophysics Shoken M. Miyama, Kohji Tomisaka, Tomoyuki Hanawa, 2012-12-06 These are the proceedings of international conference on Numerical Astrophysics 1998 NAP98 held at National Olympic Memorial Youth Center in Tokyo Japan in the period of March 10-13 1998 and hosted by the National Astronomical Observatory Japan NAOJ In the last decade numerical simulations have grown up as a major tool for astrophysics Numerical simulations give us invaluable information on complex systems and physical processes under extreme conditions which can be neither realized by experiments nor directly observed Super computers and special purpose computers may work as very large telescopes and special purpose telescopes for theoretical astrophysics respectively Numerical astrophysics ranks with other tool oriented astronomy such as radio astronomy infrared astronomy ultraviolet astronomy X-ray astronomy and gamma-ray astronomy This conference NAP98 was planned to explore recent advances in astrophysics aided by numerical simulations The subjects of the conference included the large scale structure formation galaxy formation and evolution star and planets formation accretion disks jets gravitational wave emission and plasma physics NAP98 had also sessions on numerical methods and computer science The conference was attended by 184 scientists from 21 countries We enjoyed excellent talks posters videos and discussions there are 40 oral presentations 96 posters and 16 video presentations We hope that these proceedings and accompanying CD ROM replay the friendly but inspiring atmosphere of the conference *Numerical Astrophysics* Shoken M. Miyama, Kohji Tomisaka, Tomoyuki Hanawa, 1999-03-31 This book contains all the oral and poster sessions presented at the Numerical Astrophysics 1998 symposium held in Tokyo on March 10-13 1998 It covers a wide variety of research fields from the large

scale structure of the Universe to planetary systems Astrophysics employing all kinds of supercomputers such as massive parallel computers parallel vector machines and special purpose computers are included Recent progress in numerical methods remote data analysis and special purpose computers are also reviewed This book is suitable for researchers and graduate students in astronomy astrophysics who want an overview of the present research fronts based on supercomputing

Numerical Methods in Astrophysics Peter Bodenheimer, Gregory P. Laughlin, Michal Rozyczka, Tomasz Plewa, Harold. W. Yorke, Harold W. Yorke, 2006-12-13 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 Numerical Python in Astronomy and Astrophysics Wolfram Schmidt, Marcel Völschow, 2021-07-14 This book provides a solid foundation in the Python programming language numerical methods and data analysis all embedded within the context of astronomy and astrophysics It not only enables students to learn programming with the aid of examples from these fields but also provides ample motivation for engagement in independent research The book opens by outlining the importance of computational methods and programming algorithms in contemporary astronomical and astrophysical research showing why programming in Python is a good choice for beginners The performance of basic calculations with Python is then explained with reference to for example Kepler's laws of planetary motion and gravitational and tidal forces Here essential background knowledge is provided as necessary Subsequent chapters are designed to teach the reader to define and use important functions in Python and to utilize numerical methods to solve differential equations and landmark dynamical problems in astrophysics Finally the analysis of astronomical data is discussed with various hands on examples as well as guidance on astronomical image analysis and applications of artificial neural networks *Numerical Modelling of Astrophysical Turbulence* Wolfram Schmidt, 2013-09-20 In this SpringerBrief the author considers the underlying problems and questions that are common to numerical models of turbulence in different astrophysical systems Turbulence has emerged as an important research topic in several areas of astrophysics Understanding and modeling turbulence is particularly important for the dynamics of the interstellar medium but also for the intergalactic medium as well as in stars The advancement of methods for numerical simulations of astrophysical turbulence however is still challenging because of gravity strong compressibility magnetic fields and other effects The book begins with a review of general aspects of numerical simulations of turbulence In the main part the author presents findings from his numerical studies on astrophysical turbulence and discusses the astrophysical implications He also explains in detail the numerical schemes utilized Readers will find that this book offers a compact yet comprehensive introduction *Solutions Manual for Numerical Methods in Astrophysics an Intro* Bodenheimer Peter Staff, 2006-12 **Numerical Astrophysics** Joan M. Centrella, James M. LeBlanc, Richard L. Bowers, 1985 *Computational Methods for Astrophysical Fluid Flow* Randall J. LeVeque, Dimitri

Mihalas, E.A. Dorfi, Ewald Müller, 2006-04-18 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 **Numerical Relativity** Thomas W. Baumgarte, Stuart L. Shapiro, 2010-06-24 Pedagogical introduction to numerical relativity for students and researchers entering the field and interested scientists *Explorations in Computational Physics* Devang Patil, 2025-02-20 *Explorations in Computational Physics* delves into the intricate world of computational physics offering a comprehensive guide from fundamental theories to cutting edge applications This book serves as an indispensable companion for both novice learners and seasoned researchers We cover a diverse array of topics meticulously unfolding layers of computational techniques and their applications in various branches of physics From classical mechanics simulations elucidating celestial mechanics to quantum mechanics computations unraveling atomic and subatomic realms the book navigates through the vast landscape of computational methodologies with clarity and precision Furthermore we delve into electromagnetic field simulations statistical mechanics and thermodynamics equipping readers with tools to model complex physical phenomena with accuracy and efficiency High performance computing techniques data analysis and visualization methodologies are elucidated empowering readers to harness modern computational resources in their research With lucid explanations illustrative examples and insightful discussions on emerging technologies like quantum computing and artificial intelligence *Explorations in Computational Physics* fosters a deeper understanding of computational methodologies and their transformative impact on physics research *Handbook of Numerical Methods for Hyperbolic Problems* Remi Abgrall, Chi-Wang Shu, 2017-01-16 *Handbook on Numerical Methods for Hyperbolic Problems* Applied and Modern Issues details the large amount of literature in the design analysis and application of various numerical algorithms for solving hyperbolic equations that has been produced in the last several decades This volume provides concise summaries from experts in different types of algorithms so that readers can find a variety of algorithms under different situations and become familiar with their relative advantages and limitations Provides detailed cutting edge background explanations of existing algorithms and their analysis Presents a method of different algorithms for specific applications and the relative advantages and limitations of different algorithms for engineers or those involved in applications Written by leading subject experts in each field the volumes provide breadth and depth of content coverage **Nuclear Astrophysics** Md A. Khan, 2018-02-13 In this volume the physics involved in various astrophysical processes like the synthesis of light and heavier elements explosive burning processes core collapse supernova etc have been critically addressed with minimum

mathematical derivations so as to suit all faculties of the readers For graduate students there are solved problems with exercises at the end of each chapter for researchers some recent works on the calculation of physical parameters of astrophysical importance like the calculation of S-factors at low energies have been included and for amateur readers there are lot of history information and discussion on the astronuclear phenomenon Please note Taylor Francis does not sell or distribute the Hardback in India Pakistan Nepal Bhutan Bangladesh and Sri Lanka

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Astronomy and Astrophysics Abstracts S. Böhme, U. Esser, H. Hefele, I. Heinrich, W. Hofmann, D. Krahn, V. R. Matas, L. D. Schmadel, G. Zech, 2013-12-14 From the reviews Astronomy and Astrophysics Abstracts has appeared in semi annual volumes since 1969 and it has already become one of the fundamental publications in the fields of astronomy astrophysics and neighbouring sciences It is the most important English language abstracting journal in the mentioned branches The abstracts are classified under more than hundred subject categories thus permitting a quick survey of the whole extended material The AAA is a

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Cellular Automata: Prospects In Astrophysical Applications - Proceedings Of The Workshop On Cellular Automata Models For Astrophysical Phenomena A Lejeune,J M Perdang,1993-11-23 This book provides a survey of the basic ideas of the cellular automaton CA modelling environment emphasising the relevance of this framework to astrophysical applications It contains introductory level lectures on lattice gases and on CA turbulence diffusion reaction processes percolation and self organised criticality Further it gives a variety of astrophysical applications including stellar oscillations galactic evolution distribution of luminous matter in the universe etc

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