



Approaches to
Numerical Relativity

Edited by
Ravi Iyer and Tomaso Regimbau

Approaches To Numerical Relativity

Miguel Alcubierre



Approaches To Numerical Relativity:

Approaches to Numerical Relativity Ray D'Inverno,1992 *Numerical Relativity* Masaru Shibata,2015-11-05 This book is composed of two parts First part describes basics in numerical relativity that is the formulations and methods for a solution of Einstein's equation and general relativistic matter field equations This part will be helpful for beginners of numerical relativity who would like to understand the content of numerical relativity and its background The second part focuses on the application of numerical relativity A wide variety of scientific numerical results are introduced focusing in particular on the merger of binary neutron stars and black holes

Introduction to 3+1 Numerical Relativity Miguel Alcubierre,2008-04-10 This book is a self contained introduction to the field of numerical relativity Starting from basic general relativity it introduces all the concepts and tools necessary for the fully relativistic simulation of astrophysical systems with strong and dynamical gravitational fields

Adaptive Mesh Refinement for Pseudospectral Methods in Numerical Relativity Sarah Renkhoff,2023* Across all of computational physics a central problem is that of discretization from the choice of resolution in simple finite difference approaches to the details of more intricate discretization schemes such as spectral elements The choice of discretization decides the numerical solution space as well as the properties of numerical methods such as their convergence and stability For this reason the effective use of any numerical scheme requires a proper understanding of the underlying discretization scheme and its parameters In particular modern numerical methods often incorporate adaptive discretization schemes utilizing heterogeneous meshes that change with time In this work we will explore one such method in the form of a state of the art numerical relativity code and the implementation of an adaptive mesh refinement AMR scheme within it We describe in detail its features and the resulting properties as it is used to solve physical problems in the form of hyperbolic partial differential equations and we examine the scaling behavior of the resulting method We also present results obtained using this scheme in the form of simulations of the critical collapse of gravitational waves that were made possible by the AMR system showing some evidence of both self similarity and universality in this system Finally we study a suite of several challenging test cases beginning with a simple two dimensional wave equation with an added nonlinearity which results in critical behavior for certain choices of initial data then moving on to the collapse of a real scalar field minimally coupled to general relativity in spherical symmetry Finally we use the collapse of gravitational waves in vacuum in axisymmetry as our third test case We use these example problems to evaluate the gains in terms of accuracy as well as efficiency that are obtained through the use of adaptive resolutions

Analytical and Numerical Approaches to Mathematical Relativity Jörg Frauendiener,Domenico J. W. Giulini,Volker Perlick,2009-09-02 General relativity ranks among the most accurately tested fundamental theories in all of physics Deficiencies in mathematical and conceptual understanding still exist hampering further progress This book collects surveys by experts in mathematical relativity writing about the current status of and problems in their fields There are four contributions for each of the

following mathematical areas differential geometry and differential topology analytical methods and differential equations and numerical methods

Studying Compact Star Equation of States with General Relativistic Initial Data Approach Enping Zhou, 2020-04-03 This book focuses on the equation of state EoS of compact stars particularly the intriguing possibility of the quark star model The EoS of compact stars is the subject of ongoing debates among astrophysicists and particle physicists due to the non perturbative property of strong interaction at low energy scales The book investigates the tidal deformability and maximum mass of rotating quark stars and triaxially rotating quark stars and compares them with those of neutron stars to reveal significant differences Lastly by combining the latest observations of GW170817 the book suggests potential ways to distinguish between the neutron star and quark star models

A Hyperbolic Tetrad Approach to Numerical Relativity Luisa T. Buchman, 2003

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

Quasi-Normal Modes, Non-Selfadjoint Operators and Pseudospectrum: an Interdisciplinary Approach Jose Luis Jaramillo, Piotr Bizon, Edgar Gasperin, 2026-02-13 Quasi normal modes namely the complex frequencies encoding the linear response of resonators under tiny perturbations have acquired major importance in recent years in different settings of physics ranging from astrophysical and theoretical problems in gravitational physics to the study of scattering properties of optical nanoresonators Beyond physics the subject makes direct contact with the study of the spectral and dynamical properties of non selfadjoint operators a very active area of current research in applied and fundamental mathematics with direct applications in physics from hydrodynamics and turbulence to non Hermitian quantum mechanics In spite of these converging complementary interests and working knowledge research interchanges among the involved subcommunities seem quite scarce In this setting the central notion of Pseudospectrum provides a systematic framework furnishing a common arena to this interdisciplinary field of research namely a crossroad in the physics and mathematics of open non conservative systems The general goal of this Research Topic is to bring to the front line of physics research the qualitative and quantitative features that are specific to systems whose dynamics is governed by non selfadjoint operators This generic goal is concretely articulated around the Pseudospectrum notion a key concept in the spectral theory of non selfadjoint more generally non normal operators In this context the main focus will be placed on the study of the structural stability of the spectrum of non selfadjoint operators In particular the calculation of quasi normal modes in a variety of physical scenarios provides a singularly timely problem

Indeed the recent introduction of the Pseudospectrum in gravitation physics namely in the study of the spectral instability of quasi normal modes of black holes has raised a number of questions that remain open and are urgent to answer in the context of astrophysical compact objects as sources of gravitational waves Crucially this research problem transcends the gravitational context making contact with other disciplines such as optics Complementary to this main spectral instability focus and taking the Pseudospectrum as a bridge to the broader setting of non modal analysis largely developed in fluid and turbulence physics attention will be placed to dynamical transients and pseudo resonances The ultimate goal is the threading of an interdisciplinary research community framed around the application of non selfadjoint operator concepts and tools in physics Contributions to this Research Topic are expected to address a question directly related or motivated by the physics and or mathematics of non selfadjoint operators Among the possible topics to be covered we can mention i Formulations of quasi normal modes as a spectral non selfadjoint problem with particular attention to hyperboloidal methods and spectral instability ii Mathematical and physical aspects of other non selfadjoint spectral problems iii Application of the Pseudospectrum in spectral dynamical settings in physics gravitation optics fluids quantum mechanics or applied mathematics iv Resonant quasi normal mode expansions of scattered fields and interplay with spectral instability v Implications of the latter point on the data analysis of exponentially damped oscillating signals This list is not exhaustive but only indicative and open to consideration of affine subjects Contributions can be in the form of an original research article but given the need of building a common research framework contribution in the form of mini reviews and perspectives are particularly welcome Please note that the Topic Editors will accept only B Type Articles Mini Review Perspective and Brief Research Report

Recent Progress on Gravity Tests Cosimo Bambi,Alejandro Cárdenas-Avenidaño,2024-07-09 Einstein's theory of general relativity is one of the pillars of modern physics and it is our standard framework for describing gravitational fields and the spacetime structure So far general relativity has passed all experimental tests and agrees with observations However the past few years have seen remarkable observational improvements and new techniques that continually challenge the theory's predictions routinely detect the gravitational wave signals from the coalescence of black holes and neutron stars can image the supermassive black holes at the center of our Galaxy and of the galaxy M87 can analyze the properties of the X ray radiation emitted from the very inner part of the accretion disks of several black holes and keep improving laboratory and Solar System experiments This book offers an updated self consistent overview future perspectives and challenges of experimental and observational tests of gravity with both gravitational and electromagnetic spectra It includes the recent results of laboratory tests of gravity solar system experiments tests of gravity in the strong field regime with astrophysical compact objects and tests of gravity on large scales with cosmological observations

Handbook of Gravitational Wave Astronomy Cosimo Bambi,Stavros Katsanevas,Konstantinos D. Kokkotas,2022-07-02 This handbook provides an updated comprehensive description of gravitational wave astronomy In the first part it reviews gravitational

wave experiments from ground and space based laser interferometers to pulsar timing arrays and indirect detection from the cosmic microwave background In the second part it discusses a number of astrophysical and cosmological gravitational wave sources including black holes neutron stars possible more exotic objects and sources in the early Universe The third part of the book reviews the methods to calculate gravitational waveforms The fourth and last part of the book covers techniques employed in gravitational wave astronomy data analysis This book represents both a valuable resource for graduate students and an important reference for researchers in gravitational wave astronomy

Analytical and Numerical Approaches to Mathematical Relativity Jörg Frauendiener, Domenico J. W. Giulini, 2006-03-09 General relativity ranks among the most accurately tested fundamental theories in all of physics Deficiencies in mathematical and conceptual understanding still exist hampering further progress This book collects surveys by experts in mathematical relativity writing about the current status of and problems in their fields There are four contributions for each of the following mathematical areas differential geometry and differential topology analytical methods and differential equations and numerical methods

CRSR. Cornell University. Center for Radiophysics and Space Research, 1995

Elements of Numerical Relativity Carles Bona, Carlos Palenzuela-Luque, 2005-07-07 Spurred by the current development of numerous large scale projects for detecting gravitational radiation with the aim to open a completely new window to the observable Universe numerical relativity has become a major field of research over the past years Indeed numerical relativity is the standard approach when studying potential sources of gravitational waves where strong fields and relativistic velocities are part of any physical scenario This book can be considered a primer for both graduate students and non specialist researchers wishing to enter the field Starting from the most basic insights and aspects of numerical relativity Elements of Numerical Relativity develops coherent guidelines for the reliable and convenient selection of each of the following key aspects evolution formalism gauge initial and boundary conditions as well as various numerical algorithms The tests and applications proposed in this book can be performed on a standard PC

Physics Briefs , 1994 SIAM Journal on Scientific Computing , 2007 *Encyclopedia of Mathematical Physics* Jean-Pierre Francoise, Gregory L. Naber, Sheung Tsun Tsou, 2006 The Encyclopedia of Mathematical Physics provides a complete resource for researchers students and lecturers with an interest in mathematical physics It enables readers to access basic information on topics peripheral to their own areas to provide a repository of the core information in the area that can be used to refresh the researcher s own memory banks and aid teachers in directing students to entries relevant to their course work The Encyclopedia does contain information that has been distilled organised and presented as a complete reference tool to the user and a landmark to the body of knowledge that has accumulated in this domain It also is a stimulus for new researchers working in mathematical physics or in areas using the methods originating from work in mathematical physics by providing them with focused high quality background information Editorial Board Jean Pierre Fran oise Universit Pierre et Marie Curie Paris France Gregory L Naber Drexel University Philadelphia PA USA Tsou

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