# Relativistic Hydrodynamics Luciano Rezzolla

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PSC 2021.04.09 Luciano Rezzolla, Goethe University of FrankfurtSimulations of Binary Neutron Stars: Mathematical Foundations - Lecture 1/4 | Luciano Rezzolla Simulations of Binary Neutron Stars: Mathematical Foundations - Lecture 2/4 | Luciano Rezzolla Junior's Meeting – Relativistic Hydro

01 Romatschke Lectures on Relativistic Hydrodynamics: Diffusion

Making black holes visible (long version)Simulations of Binary Neutron Stars: General Phenomenology - Lecture 3/4 | Luciano Rezzolla Deconstructing relativistic fluid dynamics General Relativistic Magnetohydrodynamics: Theory and Numerical Simulations #3/5 The First Image of a Black Hole | Luciano Rezzolla Pushing the limits of hydrodynamics Before the Big Bang 1O : Black Hole Genesis Neutron Stars (Intro Astronomy module 10, lecture 3) La prima immagine di un buco nero | Luciano Rezzolla | TEDxFoggia Neutron Star Mergers and the Origin of the Elements - Eliot Quataert - 03/01/2019 Before the Big Bang 7: An Eternal Cyclic Universe, CCC revisited \u0026 Twistor Theory Andrea Ghez - Our Galactic Center: A Unique Laboratory for the Physics \u0026 Astrophysics of Black Holes Mod-01 Lec-04 Momentum and Energy Equations

Realistic Fluid Simulations

Relativistic Fluid Dynamics: From Particle Colliders to Neutron Star MergersSimulations of Binary Neutron Stars: General Phenomenology- Lecture 4/4 | Luciano Rezzolla 05 Romatschke Lectures On Relativistic Hydrodynamics: AdS/CFT GRMHD Simulations Webinar Andrei Starinets (Univ. of Oxford): Holography, Finite Temperature QFT and Hydrodynamics - Lecture 3 Plenary talk - Alessandro Gabbana - Relativistic Lattice Boltzmann Methods: Theory and Applications Nikhef interview about gravitational waves with Luciano Rezzolla Prof. Nils Andersson: Relativistic Fluid Flows David Neilsen (1) -Introduction to numerical hydrodynamics Relativistic Hydrodynamics Luciano Rezzolla
Perseus is an outstanding case in which to study the physics of relativistic plasma and thermal gas, and the interplay between galactic nuclei and galaxy clusters. Ground and space observatories have ...

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.

Relativistic hydrodynamics is a very successful theoretical framework to describe the dynamics of matter from scales as small as those of colliding elementary particles, up to the largest scales in the universe. This book provides an up-to-date, lively, and approachable introduction to the mathematical formalism, numerical techniques, and applications of relativistic hydrodynamics. The topic is typically covered either by very formal or by very phenomenological books, but is instead presented here in a form that will be appreciated both by students and researchers in the field. The topics covered in the book are the results of work carried out over the last 40 years, which can be found in rather technical research articles with dissimilar notations and styles. The book is not just a collection of scattered information, but a well-organized description of relativistic hydrodynamics, from the basic principles of statistical kinetic theory, down to the technical aspects of numerical methods devised for the solution of the equations, and over to the applications in modern physics and astrophysics. Numerous figures, diagrams, and a variety of exercises aid the material in the book. The most obvious applications of this work range from astrophysics (black holes, neutron stars, gamma-ray bursts, and active galaxies) to cosmology (early-universe hydrodynamics and phase transitions) and particle physics (heavy-ion collisions). It is often said that fluids are either seen as solutions of partial differential equations or as "wet". Fluids in this book are definitely wet, but the mathematical beauty of differential equations is not washed out.

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This book summarizes the recent progress in the physics and astrophysics of neutron stars and, most importantly, it identifies and develops effective strategies to explore, both theoretically and observationally, the many remaining open questions in the field. Because of its significance in the solution of many fundamental questions in nuclear physics, astrophysics and gravitational physics, the study of neutron stars has seen enormous progress over the last years and has been very successful in improving our understanding in these fascinating compact objects. The book addresses a wide spectrum of readers, from students to senior researchers. Thirteen chapters written by internationally renowned experts offer a thorough overview of the various facets of this interdisciplinary science, from neutron star formation in supernovae, pulsars, equations of state super dense matter, gravitational wave emission, to alternative theories of gravity. The book was initiated by the European Cooperation in Science and Technology (COST) Action MP1304 Exploring fundamental physics with compact stars (NewCompStar).

This book offers an overview of the fundamental dynamical processes, which are necessary to understand astrophysical phenomena, from the viewpoint of hydrodynamics, magnetohydrodynamics, and radiation hydrodynamics. The book consists of three parts: The first discusses the fundamentals of hydrodynamics necessary to understand the dynamics of astrophysical objects such as stars, interstellar gases and accretion disks. The second part reviews the interactions between gases and magnetic fields on fluid motions the magnetohydrodynamics highlighting the important role of magnetic fields in dynamical phenomena under astrophysical environments. The third part focuses on radiation hydrodynamics, introducing the hydrodynamic phenomena characterized by the coupling of radiation and gas motions and further on relativistic radiation hydrodynamics. Intended as a pedagogical introduction for advanced undergraduate and graduate students, it also provides comprehensive coverage of the fundamentals of astrophysical fluid dynamics, making it an effective resource not only for graduate courses, but also for beginners wanting to learn about hydrodynamics, magnetohydrodynamics, and radiation hydrodynamics in astrophysics independently.

Relativistic Astrophysics brings together important astronomical discoveries and the significant achievements, as well as the difficulties in the field of relativistic astrophysics. This book is divided into 10 chapters that tackle some aspects of the field, including the gravitational field, stellar equilibrium, black holes, and cosmology. The opening chapters introduce the theories to delineate gravitational field and the elements of relativistic thermodynamics and hydrodynamics. The succeeding chapters deal with the gravitational fields in matter; stellar equilibrium and general relativity stability; and the properties of pulsar, rotating and neutron stars. The discussion then shifts to the association between gravitational collapse and black holes, as well as the astrophysical investigations of neutron stars and black holes. The final chapters examine the principles of gravitational waves and advances in understanding the field of cosmology. This book will be of great value to astrophysicists and related scientists.

Aimed at students and researchers entering the field, this pedagogical introduction to numerical relativity will also interest scientists seeking a broad survey of its challenges and achievements. Assuming only a basic knowledge of classical general relativity, the book develops the mathematical formalism from first principles, and then highlights some of the pioneering simulations involving black holes and neutron stars, gravitational collapse and gravitational waves. The book contains 300 exercises to help readers master new material as it is presented. Numerous illustrations, many in color, assist in visualizing new geometric concepts and highlighting the results of computer simulations. Summary boxes encapsulate some of the most important results for quick reference. Applications covered include calculations of coalescing binary black holes and binary neutron stars, rotating stars, colliding star clusters, gravitational and magnetorotational collapse, critical phenomena, the generation of gravitational waves, and other topics of current physical and astrophysical significance.

The masses of neutron stars are limited by an instability to gravitational collapse and an instability driven by gravitational waves limits their spin. Their oscillations are relevant to x-ray observations of accreting binaries and to gravitational wave observations of neutron stars formed during the coalescence of double neutron-star systems. This volume includes more than forty years of research to provide graduate students and researchers in astrophysics, gravitational physics and astronomy with the first self-contained treatment of the structure, stability and oscillations of rotating neutron stars. This monograph treats the equations of stellar equilibrium; key approximations, including slow rotation and perturbations of spherical and rotating stars; stability theory and its applications, from convective stability to the r-mode instability; and numerical methods for computing equilibrium configurations and the nonlinear evolution of their oscillations. The presentation of fundamental equations, results and applications is accessible to readers who do not need the detailed derivations.

This book introduces the modern field of 3+1 numerical relativity. The book has been written in a way as to be as self-contained as possible, and only assumes a basic knowledge of special relativity. Starting from a brief introduction to general relativity, it discusses the different concepts and tools necessary for the fully consistent numerical simulation of relativistic astrophysical systems, with strong and dynamical gravitational fields. Among the topics discussed in detail are the following: the initial data problem, hyperbolic reductions of the field equations, gauge conditions, the evolution of black hole space-times, relativistic hydrodynamics, gravitational wave extraction and numerical methods. There is also a final chapter with examples of some simple numerical space-times. The book is aimed at both graduate students and researchers in physics and astrophysics, and at those interested in relativistic astrophysics.