Gravitational Wave Physics And Astronomy An

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General Relativity and Gravitational Waves - Sanjeev Dhurandhar 2022-02-16

This book serves as a textbook for senior undergraduate students who are learning the subject of general relativity and gravitational waves for the first time. Both authors have been teaching the course in various forms for a few decades and have designed the book as a one stop book at basic level including derivations and exercises. A spectacular prediction of general relativity is gravitational waves. Gravitational waves were first detected by the LIGO detectors in 2015, hundred years after their prediction. Both authors are part of the LIGO Science Collaboration and were authors on the discovery paper. Therefore, a strong motivation for this book is to provide the essential concepts of general relativity theory and gravitational waves with their modern applications to students and to researchers who are new to the multi-disciplinary field of gravitational wave astronomy. One of the advanced topics covered in this book is the fundamentals of gravitational wave data analysis, filling a gap in textbooks on general relativity. The topic blends smoothly with other chapters in the book not only because of the common area of research, but it uses similar differential geometric and algebraic tools that are used in general relativity.

Advanced Interferometers and the Search for Gravitational Waves - Massimo Bassan 2014-07-08

The search for gravitational radiation with optical interferometers is gaining momentum worldwide. Beside the VIRGO and GEO gravitational wave observatories in Europe and the two LIGOs in the United States, which have operated successfully during the past decade, further observatories are being completed (KAGRA in Japan) or planned (ILIGO in India). The sensitivity of the current observatories, although spectacular, has not allowed direct discovery of gravitational waves. The advanced detectors (Advanced LIGO and Advanced Virgo) at present in the development phase will improve sensitivity by a factor of 10, probing the universe up to 200 Mpc for signal from inspiraling binary compact stars. This book covers all experimental aspects of the search for gravitational radiation with optical interferometers. Every facet of the technological development underlying the evolution of advanced interferometers is thoroughly described, from configuration to optics and coatings and from thermal compensation to suspensions and controls. All key ingredients of an advanced detector are covered, including the solutions implemented in first-generation detectors, their limitations, and how to overcome them. Each issue is addressed with special reference to the solution adopted for Advanced VIRGO but constant attention is also paid to other strategies, in particular those chosen for Advanced LIGO.

General Relativity and Gravitational Waves - Sanjeev Dhurandhar 2022-03-10

This book serves as a textbook for senior undergraduate students who are learning the subject of general relativity and gravitational waves for the first time. Both authors have been teaching the course in various forms for a few decades and have designed the book as a one stop book at basic level including derivations and exercises. A spectacular prediction of general relativity is gravitational waves. Gravitational waves were first detected by the LIGO detectors in 2015, hundred years after their prediction. Both authors are part of the LIGO Science Collaboration and were authors on the discovery paper. Therefore, a strong motivation for this book is to provide the essential concepts of general relativity theory and gravitational waves with their modern applications to students and to researchers who are new to the multi-disciplinary field of gravitational wave astronomy. One of the advanced topics covered in this book is the fundamentals of gravitational wave data analysis, filling a gap in textbooks on general relativity. The topic blends smoothly with other chapters in the book not only because of the common area of research, but it uses similar differential geometric and algebraic tools that are used in general relativity.

Quantum Field Theory in Curved Spacetime - Leonard Parker 2009-08-20

Quantum field theory in curved spacetime has been remarkably fruitful. It can be used to explain how the large-scale structure of the universe and the anisotropies of the cosmic background radiation that we observe today first arose. Similarly, it provides a deep connection between general relativity, thermodynamics, and quantum field theory. This book develops quantum field theory in curved spacetime in a pedagogical style, suitable for graduate students. The authors present detailed, physically motivated, derivations of cosmological and black hole processes in which curved spacetime plays a key role. They explain how such processes in the rapidly expanding early universe leave observable consequences today, and how in the context of evaporating black holes, these processes uncover deep connections between gravitation and elementary particles. The authors also lucidly describe many other aspects of free and interacting quantized fields in curved spacetime.

Gravitational-Wave Physics and Astronomy - Jolien D. E. Creighton 2011-10-17

This most up-to-date, one-stop reference combines coverage of both theory and observational techniques, with introductory sections to bring all readers up to the same level. Written by outstanding researchers directly involved with the scientific program of the Laser Interferometer Gravitational-Wave Observatory (LIGO), the book begins with a brief review of general relativity before going on to describe the physics of gravitational waves and the astrophysical sources of gravitational radiation. Further sections cover gravitational wave detectors, data analysis, and the outlook of gravitational wave astronomy and astrophysics.

Exploring the Early Universe with Gravitational Waves - Laura Bianca Bethke 2015-05-20

This work investigates gravitational wave production in the early universe and identifies potentially observable features, thereby paving the way for future gravitational wave experiments. It focuses on gravitational wave production in two scenarios: inflation in a model inspired by loop quantum gravity, and preheating at the end of inflation. In the first part, it is demonstrated that gravitational waves' spectrum differs from the result obtained using ordinary general relativity, with potentially observable consequences that could yield insights into quantum gravity. In the second part, it is shown that the cosmic gravitational wave background is anisotropic at a level that could be detected by future experiments. Gravitational waves promise to be an rich source of information on the early universe. To them, the universe has been transparent from its earliest moments, so they can give us an unobstructed view of the Big Bang and a means to probe the fundamental laws of nature at very high energies.

General Relativity and its Applications - Valeria Ferrari 2020-12-22

Containing the latest, groundbreaking discoveries in the field, this text outlines the basics of Einstein's theory of gravity with a focus on its most

important astrophysical consequences, including stellar structures, black holes and the physics of gravitational waves. Blending advanced topics - usually not found in introductory textbooks - with examples, pedagogical boxes, mathematical tools and practical applications of the theory, this textbook maximises learning opportunities and is ideal for master and graduate students in Physics and Astronomy. Key features: • Provides a self-contained and consistent treatment of the subject that does not require advanced previous knowledge of the field. • Explores the subject with a new focus on gravitational waves and astrophysical relativity, unlike current introductory textbooks. • Fully up-to-date, containing the latest developments and discoveries in the field.

Gravitational-Wave Physics and Astronomy - Jolien D. E. Creighton 2012-01-09

This most up-to-date, one-stop reference combines coverage of both theory and observational techniques, with introductory sections to bring all readers up to the same level. Written by outstanding researchers directly involved with the scientific program of the Laser Interferometer Gravitational-Wave Observatory (LIGO), the book begins with a brief review of general relativity before going on to describe the physics of gravitational waves and the astrophysical sources of gravitational radiation. Further sections cover gravitational wave detectors, data analysis, and the outlook of gravitational wave astronomy and astrophysics.

The Detection of Gravitational Waves - David G. Blair 2005-10-13

This book introduces the concepts of gravitational waves within the context of general relativity. The sources of gravitational radiation for which there is direct observational evidence and those of a more speculative nature are described. He then gives a general introduction to the methods of detection. In the subsequent chapters he has drawn together the leading scientists in the field to give a comprehensive practical and theoretical account of the physics and technology of gravitational wave detection.

Advanced Gravitational Wave Detectors - D. G. Blair 2012-02-16

Introduces the technology and reviews the experimental issues; a valuable reference for graduate students and researchers in physics and astrophysics.

Fundamentals of Interferometric Gravitational Wave Detectors (Second Edition) - Peter R. Saulson 2017-04-19

'The content of the Saulsonâ (TM)s book remains valid and offers a versatile introduction to gravitational wave astronomy. The book is appropriate for undergraduate students and can be read by graduate students and researchers who want to be involved in either the theoretical or the experimental traits of the study of gravitational waves.'Contemporary PhysicsLIGO's recent discovery of gravitational waves was headline news around the world. Many people will want to understand more about what a gravitational wave is, how LIGO works, and how LIGO functions as a detector of gravitational waves.This book aims to communicate the basic logic of interferometric gravitational wave detectors to students who are new to the field. It assumes that the reader has a basic knowledge of physics, but no special familiarity with gravitational waves, with general relativity, or with the special techniques of experimental physics. All of the necessary ideas are developed in the book.The first edition was published in 1994. Since the book is aimed at explaining the physical ideas behind the design of LIGO, it stands the test of time. For the second edition, an Epilogue has been added; it brings the treatment of technical details up to date, and provides references that would allow a student to become proficient with today's designs.

Gravitational Wave Astrophysics - Carlos F. Sopuerta 2015-01-02

This book offers review chapters written by invited speakers of the 3rd Session of the Sant Cugat Forum on Astrophysics - Gravitational Waves Astrophysics. All chapters have been peer reviewed. The book goes beyond normal conference proceedings in that it provides a wide panorama of the astrophysics of gravitational waves and serves as a reference work for researchers in the field.

Ripples in Spacetime - Govert Schilling 2017-07-31

A spacetime appetizer -- Relatively speaking -- Einstein on trial -- Wave talk and bar fights -- The lives of stars -- Clockwork precision -- Laser

quest -- The path to perfection -- Creation stories -- Cold case -- Gotcha -- Black magic -- Nanoscience -- Follow-up questions -- Space invaders -- Surf's up for Einstein wave astronomy

Einstein Was Right - Jed Z. Buchwald 2020-10-13

An authoritative interdisciplinary account of the historic discovery of gravitational waves In 1915, Albert Einstein predicted the existence of gravitational waves—ripples in the fabric of spacetime caused by the movement of large masses—as part of the theory of general relativity. A century later, researchers with the Laser Interferometer Gravitational-Wave Observatory (LIGO) confirmed Einstein's prediction, detecting gravitational waves generated by the collision of two black holes. Shedding new light on the hundred-year history of this momentous achievement, Einstein Was Right brings together essays by two of the physicists who won the Nobel Prize for their instrumental roles in the discovery, along with contributions by leading scholars who offer unparalleled insights into one of the most significant scientific breakthroughs of our time. This illuminating book features an introduction by Tilman Sauer and invaluable firsthand perspectives on the history and significance of the LIGO consortium by physicists Barry Barish and Kip Thorne. Theoretical physicist Alessandra Buonanno discusses the new possibilities opened by gravitational wave astronomy, and sociologist of science Harry Collins and historians of science Diana Kormos Buchwald, Daniel Kennefick, and Jürgen Renn provide further insights into the history of relativity and LIGO. The book closes with a reflection by philosopher Don Howard on the significance of Einstein's theory for the philosophy of science. Edited by Jed Buchwald, Einstein Was Right is a compelling and thought-provoking account of one of the most thrilling scientific discoveries of the modern age.

The Physics and Astrophysics of Neutron Stars - Luciano Rezzolla 2019-01-09

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).

Superradiance - Richard Brito 2020-08-21

This book focuses on one mechanism in black hole physics which has proven to be universal, multifaceted and with a rich phenomenology: rotational superradiance. This is an energy extraction process, whereby black holes can deposit their rotational energy in their surroundings, leading to Penrose processes, black-hole bombs, and even Hawking radiation. Black holes are key players in star formation mechanisms and as engines to some of the most violent events in our universe. Their simplicity and compactness make them perfect laboratories, ideally suited to probe new fields or modifications to the theory of gravity. Thus, black holes can also be used to probe some of the most important open problems in physics, including the nature of dark matter or the strong CP problem in particle physics. This monograph is directed to researchers and graduate students and provides a unified view of the subject, covering the theoretical machinery, experimental efforts in the laboratory, and astrophysics searches. It is focused on recent developments and works out a number of novel examples and applications, ranging from fundamental physics to astrophysics. Non-specialists with a scientific background should also find this text a valuable resource for understanding the critical issues of contemporary research in black-hole physics. This second edition stresses the role of

ergoregions in superradiance, and completes its catalogue of energy-extraction processes. It presents a unified description of instabilities of spinning black holes in the presence of massive fields. Finally, it covers the first experimental observation of superradiance, and reviews the state-of-the-art in the searches for new light fields in the universe using superradiance as a mechanism.

Gravitational Waves and Cosmology - E. Coccia 2020-08-31

The past twenty years have seen a number of breakthroughs in astrophysics and cosmology, some of which have been awarded Nobel prizes. These physics triumphs highlight the fact that while students need a solid grounding in the fundamentals of astrophysics and cosmology, sight of the basics of the fundamental interactions in physics must not be lost. This book presents papers based on lectures given at the 200th Course of the International School of Physics “Enrico Fermi”, on Gravitation and Cosmology, held in Varenna, Italy, from 3 - 12 July 2017. The aim of the school was to expose students to state-of-the-art research in the field of gravitational waves and cosmology, from both a theoretical and experimental point of view. Lectures were organized in such a way as to foster interaction between the two communities, and a wide range of topics was addressed. In the gravitational waves section, topics covered include experimental issues connected with gravitational wave detection and the new field of multi-messenger astronomy, as well as more astrophysical aspects. In the section on cosmology, there are contributions on the early universe, on the cosmic microwave background (CMB) and on redshift surveys. Other areas covered include a review of inflationary scenarios; the non-Gaussian features of primordial density fluctuations; and the physical mechanisms responsible for the spectral distortions of the blackbody spectrum of the CMB. The book provides an overview of important research developments and will be of interest to all students of gravitation and cosmology.

Probes of Multimessenger Astrophysics - Maurizio Spurio 2018-12-07

"I have taught from and enjoyed the first edition of the book. The selection of topics is the best I've seen. Maurizio Spurio gives very clear presentations using a generous amount of observational data. " James Matthews (Louisiana State University) This is the second edition of an introduction to “multi-messenger” astrophysics. It covers the many different aspects connecting particle physics with astrophysics and cosmology and introduces high-energy astrophysics using different probes: the electromagnetic radiation, with techniques developed by traditional astronomy; charged cosmic rays, gamma-rays and neutrinos, with methods developed in high-energy laboratories; and gravitational waves, recently observed using laser interferometers. The book offers a comprehensive and systematic approach to the theoretical background and the experimental aspects of the study of the high-energy universe. The breakthrough discovery of gravitational waves motivated this new edition of the book, to offer a more global and multimessenger vision of high-energy astrophysics. This second edition is updated and enriched with substantial new materials also deriving from the results obtained at the LIGO/Virgo observatories. For the first time it is now possible to draw the connection between gravitational waves, traditional astronomical observations and other probes (in particular, gamma-rays and neutrinos). The book draws on the extensive courses of Professor Maurizio Spurio at the University of Bologna and it is aimed at graduate students and post-graduate researchers with a basic understanding of particle and nuclear physics. It will also be of interest to particle physicists working in accelerator/collider physics who are keen to understand the mechanisms of the largest accelerators in the Universe.

Gravitational Waves - Ajit Kembhavi 2020-08-06

Gravitational waves were first predicted by Albert Einstein in 1916, a year after the development of his new theory of gravitation known as the general theory of relativity. This theory established gravitation as the curvature of space-time produced by matter and energy. To be discernible even to the most sensitive instruments on Earth, the waves have to be produced by immensely massive objects like black holes and neutron stars which are rotating around each other, or in the extreme situations which prevail in the very early ages of the Universe. This book presents the story of the prediction of gravitational waves by Albert Einstein, the early attempts to detect the waves, the development of the

LIGO detector, the first detection in 2016, the subsequent detections and their implications. All concepts are described in some detail, without the use of any mathematics and advanced physics which are needed for a full understanding of the subject. The book also contains description of electromagnetism, Einstein's special theory and general theory of relativity, white dwarfs, neutron stars and black holes and other concepts which are needed for understanding gravitational waves and their effects. Also described are the LIGO detectors and the cutting edge technology that goes into building them, and the extremely accurate measurements that are needed to detect gravitational waves. The book covers these ideas in a simple and lucid fashion which should be accessible to all interested readers. The first detection of gravitational waves was given a lot of space in the print and electronic media. So, the curiosity of the non-technical audience has been aroused about what gravitational waves really are and why they are so important. This book seeks to answer such questions.

Gravitational Waves - Michele Maggiore 2018

The two-volume book Gravitational Waves provides a comprehensive and detailed account of the physics of gravitational waves. While Volume 1 is devoted to the theory and experiments, Volume 2 discusses what can be learned from gravitational waves in astrophysics and in cosmology, by systematizing a large body of theoretical developments that have taken place over the last decades. The second volume also includes a detailed discussion of the first direct detections of gravitational waves. In the author's typical style, the theoretical results are generally derived afresh, clarifying or streamlining the existing derivations whenever possible, and providing a coherent and consistent picture of the field. The first volume of Gravitational Waves , which appeared in 2007, has established itself as the standard reference in the field. The scientific community has eagerly awaited this second volume. The recent direct detection of gravitational waves makes the topics in this book particularly timely.

Principles of Gravitational Lensing - Arthur B. Congdon 2018-12-01

This textbook provides an introduction to gravitational lensing, which has become an invaluable tool in modern astrophysics, with applications that range from finding planets orbiting distant stars to understanding how dark matter and dark energy conspired to form the cosmic structures we see today. Principles of Gravitational Lensing begins with Einstein's prediction that gravity bends light, and shows how that fundamental idea has spawned a rich field of study over the past century. The gravitational deflection of light was first detected by Eddington during a solar eclipse in May 1919, launching Einstein and his theory of relativity into public view. Yet the possibility of using the phenomenon to unlock mysteries of the Universe seemed remote, given the technology of the day. Theoretical work was carried out sporadically over the next six decades, but only with the discovery of the system Q0957+561 in 1979 was gravitational lensing transformed from a curiosity of general relativity into a practical observational tool. This book describes how the three subfields known as strong lensing, weak lensing, and microlensing have grown independently but become increasingly intertwined. Drawing on their research experience, Congdon and Keeton begin with the basic physics of light bending, then present the mathematical foundations of gravitational lensing, building up to current research topics in a clear and systematic way. Relevant background material from physics and mathematics is included, making the book self-contained. The derivations and explanations are supplemented by exercises designed to help students master the theoretical concepts as well as the methods that drive current research. An extensive bibliography guides those wishing to delve more deeply into particular areas of interest. Principles of Gravitational Lensing is ideal for advanced students and seasoned researchers looking to penetrate this thriving subject and even contribute research of their own.

Understanding Gravitational Waves - C. R. Kitchin 2021-09-23

The birth of a completely new branch of observational astronomy is a rare and exciting occurrence. For a long time, our theories about gravitational waves—proposed by Albert Einstein and others more than a hundred years ago—could never be fully proven, since we lacked the proper technology to do it. That all changed when, on September 14, 2015, instruments at the LIGO Observatory detected gravitational waves

for the first time. This book explores the nature of gravitational waves—what they are, where they come from, why they are so significant and why nobody could prove they existed before now. Written in plain language and interspersed with additional explanatory tutorials, it will appeal to lay readers, science enthusiasts, physical science students, amateur astronomers and to professional scientists and astronomers.

Fundamentals Of Interferometric Gravitational Wave Detectors (Second Edition) - Saulson Peter R 2017-02-16

LIGO's recent discovery of gravitational waves was headline news around the world. Many people will want to understand more about what a gravitational wave is, how LIGO works, and how LIGO functions as a detector of gravitational waves.This book aims to communicate the basic logic of interferometric gravitational wave detectors to students who are new to the field. It assumes that the reader has a basic knowledge of physics, but no special familiarity with gravitational waves, with general relativity, or with the special techniques of experimental physics. All of the necessary ideas are developed in the book.The first edition was published in 1994. Since the book is aimed at explaining the physical ideas behind the design of LIGO, it stands the test of time. For the second edition, an Epilogue has been added; it brings the treatment of technical details up to date, and provides references that would allow a student to become proficient with today's designs.

Handbook of Gravitational Wave Astronomy - Cosimo Bambi 2022-08-03

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.

Black Hole Blues and Other Songs from Outer Space - Janna Levin 2016-03-29

The authoritative story of the headline-making discovery of gravitational waves—by an eminent theoretical astrophysicist and award-winning writer. From the author of How the Universe Got Its Spots and A Madman Dreams of Turing Machines, the epic story of the scientific campaign to record the soundtrack of our universe. Black holes are dark. That is their essence. When black holes collide, they will do so unilluminated. Yet the black hole collision is an event more powerful than any since the origin of the universe. The profusion of energy will emanate as waves in the shape of spacetime: gravitational waves. No telescope will ever record the event; instead, the only evidence would be the sound of spacetime ringing. In 1916, Einstein predicted the existence of gravitational waves, his top priority after he proposed his theory of curved spacetime. One century later, we are recording the first sounds from space, the soundtrack to accompany astronomy’s silent movie. In Black Hole Blues and Other Songs from Outer Space, Janna Levin recounts the fascinating story of the obsessions, the aspirations, and the trials of the scientists who embarked on an arduous, fifty-year endeavor to capture these elusive waves. An experimental ambition that began as an amusing thought experiment, a mad idea, became the object of fixation for the original architects—Rai Weiss, Kip Thorne, and Ron Drever. Striving to make the ambition a reality, the original three gradually accumulated an international team of hundreds. As this book was written, two massive instruments of remarkably delicate sensitivity were brought to advanced capability. As the book draws to a close, five decades after the experimental ambition began, the team races to intercept a wisp of a sound with two colossal machines, hoping to succeed in time for the centenary of Einstein’s most radical idea. Janna Levin’s absorbing account of the surprises, disappointments, achievements, and risks in this unfolding story offers a portrait of modern science that is unlike anything we’ve seen before.

Modern General Relativity - Mike Guidry 2019-01-03

Einstein's general theory of relativity is widely considered to be one of the most elegant and successful scientific theories ever developed, and it is increasingly being taught in a simplified form at advanced undergraduate level within both physics and mathematics departments. Due to the increasing interest in gravitational physics, in both the academic and the public sphere, driven largely by widely-publicised developments such as the recent observations of gravitational waves, general relativity is also one of the most popular scientific topics pursued through self-study. Modern General Relativity introduces the reader to the general theory of relativity using an example-based approach, before describing some of its most important applications in cosmology and astrophysics, such as gamma-ray bursts, neutron stars, black holes, and gravitational waves. With hundreds of worked examples, explanatory boxes, and end-of-chapter problems, this textbook provides a solid foundation for understanding one of the towering achievements of twentieth-century physics.

Gravitational Waves - Hartmut Grote 2020

The historic detection of gravitational waves on September 14, 2015, prompted by the highly energetic fusion of two black holes, has made events in the universe "audible" for the first time. This expansion of the scientific sensorium has opened a new chapter in astronomy and already led to, among others, fascinating new insights about the abundance of black holes, the collision of neutron stars, and the origin of heavy chemical elements. The history of this event, which is epochal for physics, is reconstructed in this book, along with a walk-through of the main principles of how the detectors operate and a discussion of how the search for gravitational waves is conducted. The book concludes with an update of the latest detections and developments to date and a brief look into the future of this exciting research field. This book is accessible to non-specialist readers from a general audience and is also an excellent introduction to the topic for undergraduates in physics. Features: Provides an introduction to the historic discovery of gravitational waves Explains the inner workings of the detectors and the search to find the waves hidden in the data Authored by a renowned specialist involved in the ground-breaking discovery Hartmut Grote is a Professor of physics at Cardiff University, UK. His main expertise is in experimental gravitational-wave physics, and he has worked on building and improving gravitational wave detectors for over 20 years. From 2009 to 2017, he was the scientific leader of the British-German gravitational-wave detector: GEO600.

Relativity, Gravitation and Cosmology - Ta-Pei Cheng 2010

An introduction to Einstein's general theory of relativity, this work is structured so that interesting applications, such as gravitational lensing, black holes and cosmology, can be presented without the readers having to first learn the difficult mathematics of tensor calculus.

Traveling at the Speed of Thought - Daniel Kennefick 2016-03-29

Since Einstein first described them nearly a century ago, gravitational waves have been the subject of more sustained controversy than perhaps any other phenomenon in physics. These as yet undetected fluctuations in the shape of space-time were first predicted by Einstein's general theory of relativity, but only now, at the dawn of the twenty-first century, are we on the brink of finally observing them. Daniel Kennefick's landmark book takes readers through the theoretical controversies and thorny debates that raged around the subject of gravitational waves after the publication of Einstein's theory. The previously untold story of how we arrived at a settled theory of gravitational waves includes a stellar cast from the front ranks of twentieth-century physics, including Richard Feynman, Hermann Bondi, John Wheeler, Kip Thorne, and Einstein himself, who on two occasions avowed that gravitational waves do not exist, changing his mind both times. The book derives its title from a famously skeptical comment made by Arthur Stanley Eddington in 1922--namely, that "gravitational waves propagate at the speed of thought." Kennefick uses the title metaphorically to contrast the individual brilliance of each of the physicists grappling with gravitational-wave theory against the frustratingly slow progression of the field as a whole. Accessibly written and impeccably researched, this book sheds new light on the trials and conflicts that have led to the extraordinary position in which we find ourselves today--poised to bring the story of gravitational

waves full circle by directly confirming their existence for the very first time.

Gravitational Waves - Michele Maggiore 2008

The aim of this book is to become a major reference text for gravitational-wave physics, covering in detail both the experimental and the theoretical aspects. The book brings the reader to the forefront of present-day research, and assumes no previous knowledge of gravitational-wave physics.

Extracting Physics from Gravitational Waves - Tjonnie G. F. Li 2016-10-15

Tjonnie Li's thesis covers two applications of Gravitational Wave astronomy: tests of General Relativity in the strong-field regime and cosmological measurements. The first part of the thesis focuses on the so-called TIGER, i.e. Test Infrastructure for General Relativity, an innovative Bayesian framework for performing hypothesis tests of modified gravity using ground-based GW data. After developing the framework, Li simulates a variety of General Relativity deviations and demonstrates the ability of the aforementioned TIGER to measure them. The advantages of the method are nicely shown and compared to other, less generic methods. Given the extraordinary implications that would result from any measured deviation from General Relativity, it is extremely important that a rigorous statistical approach for supporting these results would be in place before the first Gravitational Wave detections begin. In developing TIGER, Tjonnie Li shows a large amount of creativity and originality, and his contribution is an important step in the direction of a possible discovery of a deviation (if any) from General Relativity. In another section, Li's thesis deals with cosmology, describing an exploratory study where the possibility of cosmological parameters measurement through gravitational wave compact binary coalescence signals associated with electromagnetic counterparts is evaluated. In particular, the study explores the capabilities of the future Einstein Telescope observatory. Although of very long term-only applicability, this is again a thorough investigation, nicely put in the context of the current and the future observational cosmology.

Gravitational-Wave Astronomy - Nils Andersson 2019-11-28

This book is an introduction to gravitational waves and related astrophysics. It provides a bridge across the range of astronomy, physics and cosmology that comes into play when trying to understand the gravitational-wave sky. Starting with Einstein's theory of gravity, chapters develop the key ideas step by step, leading up to the technology that finally caught these faint whispers from the distant universe. The second part of the book makes a direct connection with current research, introducing the relevant language and making the involved concepts less "mysterious". The book is intended to work as a platform, low enough that anyone with an elementary understanding of gravitational waves can scramble onto it, but at the same time high enough to connect readers with active research - and the many exciting discoveries that are happening right now. The first part of the book introduces the key ideas, following a general overview chapter and including a brief reminder of Einstein's theory. This part can be taught as a self-contained one semester course. The second part of the book is written to work as a collection of "set pieces" with core material that can be adapted to specific lectures and additional material that provide context and depth. A range of readers may find this book useful, including graduate students, astronomers looking for basic understanding of the gravitational-wave window to the universe, researchers analysing data from gravitational-wave detectors, and nuclear and particle physicists.

Analysis of Gravitational-Wave Data - Piotr Jaranowski 2009-08-27

Research in this field has grown considerably in recent years due to the commissioning of a world-wide network of large-scale detectors. This network collects a very large amount of data that is currently being analyzed and interpreted. This book introduces researchers entering the field, and researchers currently analyzing the data, to the field of gravitational-wave data analysis. An ideal starting point for studying the issues related to current gravitational-wave research, the book contains detailed derivations of the basic formulae related to the detectors' responses and maximum-likelihood detection. These derivations are much more complete and more pedagogical than those found in current

research papers, and will enable readers to apply general statistical concepts to the analysis of gravitational-wave signals. It also discusses new ideas on devising the efficient algorithms needed to perform data analysis.

Gravitational Waves - Isaac Carson 2017

The search for fast growing infinitesimal perturbations in the Friedmann-Lema�tre-Robertson-Walker universe within Einsteins General Relativity is regarded as very important for explanation of observational inhomogeneities such as nebulae and clusters of galaxies. Chapter One reports on numerical solutions of Hawkings equations for gravitational waves in evolutionary universe, which includes wave-matter interaction. Chapter Two presents an overview of various options of direct including of SQUID into a system for registering effects of super weak elongation or very little force. Chapter Three reviews previous work on constraining gravitational radiation from elliptically deformed pulsars with terrestrial nuclear laboratory data in light of the recent gravitational wave detection, and estimates the maximum gravitational wave strain amplitude, using an optimistic value for the breaking strain of the neutron star crust. Chapter Four explores the LIGO signal GW150914 within the braneworld scenario. Future space flight propelled by artificially-generated Gravitational Wave (GW) beam is discussed within the framework of the General Relativity theory in the final chapter of this book.

Gravitational Waves - Michele Maggiore 2018-03-09

The two-volume book Gravitational Waves provides a comprehensive and detailed account of the physics of gravitational waves. While Volume 1 is devoted to the theory and experiments, Volume 2 discusses what can be learned from gravitational waves in astrophysics and in cosmology, by systematizing a large body of theoretical developments that have taken place over the last decades. The second volume also includes a detailed discussion of the first direct detections of gravitational waves. In the author's typical style, the theoretical results are generally derived afresh, clarifying or streamlining the existing derivations whenever possible, and providing a coherent and consistent picture of the field. The first volume of Gravitational Waves , which appeared in 2007, has established itself as the standard reference in the field. The scientific community has eagerly awaited this second volume. The recent direct detection of gravitational waves makes the topics in this book particularly timely.

Nanohertz Gravitational Wave Astronomy - Stephen R. Taylor 2021-11-22

Nanohertz Gravitational Wave Astronomy explores the exciting hunt for low frequency gravitational waves by using the extraordinary timing precision of pulsars. The book takes the reader on a tour across the expansive gravitational-wave landscape, from LIGO detections to the search for polarization patterns in the Cosmic Microwave Background, then hones in on the band of nanohertz frequencies that Pulsar Timing Arrays (PTAs) are sensitive to. Within this band may lie many pairs of the most massive black holes in the entire Universe, all radiating in chorus to produce a background of gravitational waves. The book shows how such extra-Galactic gravitational waves can alter the arrival times of radio pulses emanating from monitored Galactic pulsars, and how we can use the pattern of correlated timing deviations from many pulsars to tease out the elusive signal. The book takes a pragmatic approach to data analysis, explaining how it is performed in practice within classical and Bayesian statistics, as well as the numerous strategies one can use to optimize numerical Bayesian searches in PTA analyses. It closes with a complete discussion of the data model for nanohertz gravitational wave searches, and an overview of the past achievements, present efforts, and future prospects for PTAs. The book is accessible to upper division undergraduate students and graduate students of astronomy, and also serves as a useful desk reference for experts in the field. Key features: Contains a complete derivation of the pulsar timing response to gravitational waves, and the overlap reduction function for PTAs. Presents a comprehensive overview of source astrophysics, and the dynamical influences that shape the gravitational wave signals that PTAs are sensitive to. Serves as a detailed primer on gravitational-wave data analysis and numerical Bayesian techniques for PTAs.

Gravitational-wave Astronomy - Nils Andersson (Astrophysicist) 2020

This introduction to gravitational waves and related astrophysics

provides a bridge across the range of astronomy, physics and cosmology that comes into play when trying to understand the gravitational-wave sky. Key ideas are developed step by step, leading up to the technology that caught these faint whispers from the distant universe.

Gravitational Waves in Physics and Astrophysics - M. Coleman Miller 2022-03-15

The direct detection of gravitational waves in 2015 has initiated a new era of gravitational wave astronomy, which has already paid remarkable dividends in our understanding of astrophysics and gravitational physics. Aimed at advanced undergraduates and graduate students, this book introduces gravitational waves and its many applications to cosmology, nuclear physics, astrophysics and theoretical physics. The material is presented in a pedagogical way, through Fermi estimates, and detailed explanations and discussions. The student will not only learn what gravitational waves are and how they are produced, but also how they can be used to learn about astrophysical phenomena and cosmological observations, to investigate the interior of neutron stars, and to test general relativity when black holes and neutron stars collide. Key Features: Provides a concise yet comprehensive treatment of gravitational wave physics Emphasises fundamental physical principles Provides a coherent integration of astrophysical and general relativistic intuition Includes carefully chosen problems designed to improve student intuition Written by experts in the field

Gravity's Ghost and Big Dog - Harry Collins 2014-01-23

Gravity’s Ghost and Big Dog brings to life science’s efforts to detect cosmic gravitational waves. These ripples in space-time are predicted by general relativity, and their discovery will not only demonstrate the truth of Einstein’s theories but also transform astronomy. Although no gravitational wave has ever been directly detected, the previous five years have been an especially exciting period in the field. Here sociologist Harry Collins offers readers an unprecedented view of gravitational wave research and explains what it means for an analyst to do work of this kind. Collins was embedded with the gravitational wave physicists as they confronted two possible discoveries—“Big Dog,” fully analyzed in this volume for the first time, and the “Equinox Event,” which was first chronicled by Collins in Gravity’s Ghost. Collins records the agonizing arguments that arose as the scientists worked out what they had seen and how to present it to the world, along the way demonstrating how even the most statistical of sciences rest on social and philosophical choices. Gravity’s Ghost and Big Dog draws on nearly fifty years of fieldwork observing scientists at the American Laser Interferometer Gravitational Wave Observatory and elsewhere around the world to offer an inspired commentary on the place of science in society today.

Relativistic Astrophysics of the Transient Universe - Maurice H. P. M. Van Putten 2012-07-05

"In the coming decade, the transient universe will be mapped out in great detail by the emerging wide-field multiwavelength surveys, neutrino and gravitational-wave detectors, promising to probe the astronomical and physical origin of the most extreme relativistic sources. This volume introduces the physical processes relevant to the source modeling of the transient universe. Ideal for graduate students and researchers in astrophysics, this book gives a unified treatment of electromagnetic, hadronic and gravitational radiation processes associated with relativistic outflows from compact objects. After introducing the source classes, the authors set out the various radiation processes associated with magneto-hydrodynamic flows, such as blast waves, winds,jets and accretion. Readers will gain an understanding of the theory, observations and some methods of data analysis for gravitational-wave data"--