

What is a black hole?

A celestial object so dense that no matter or energy can escape its gravitational pull

Event horizon

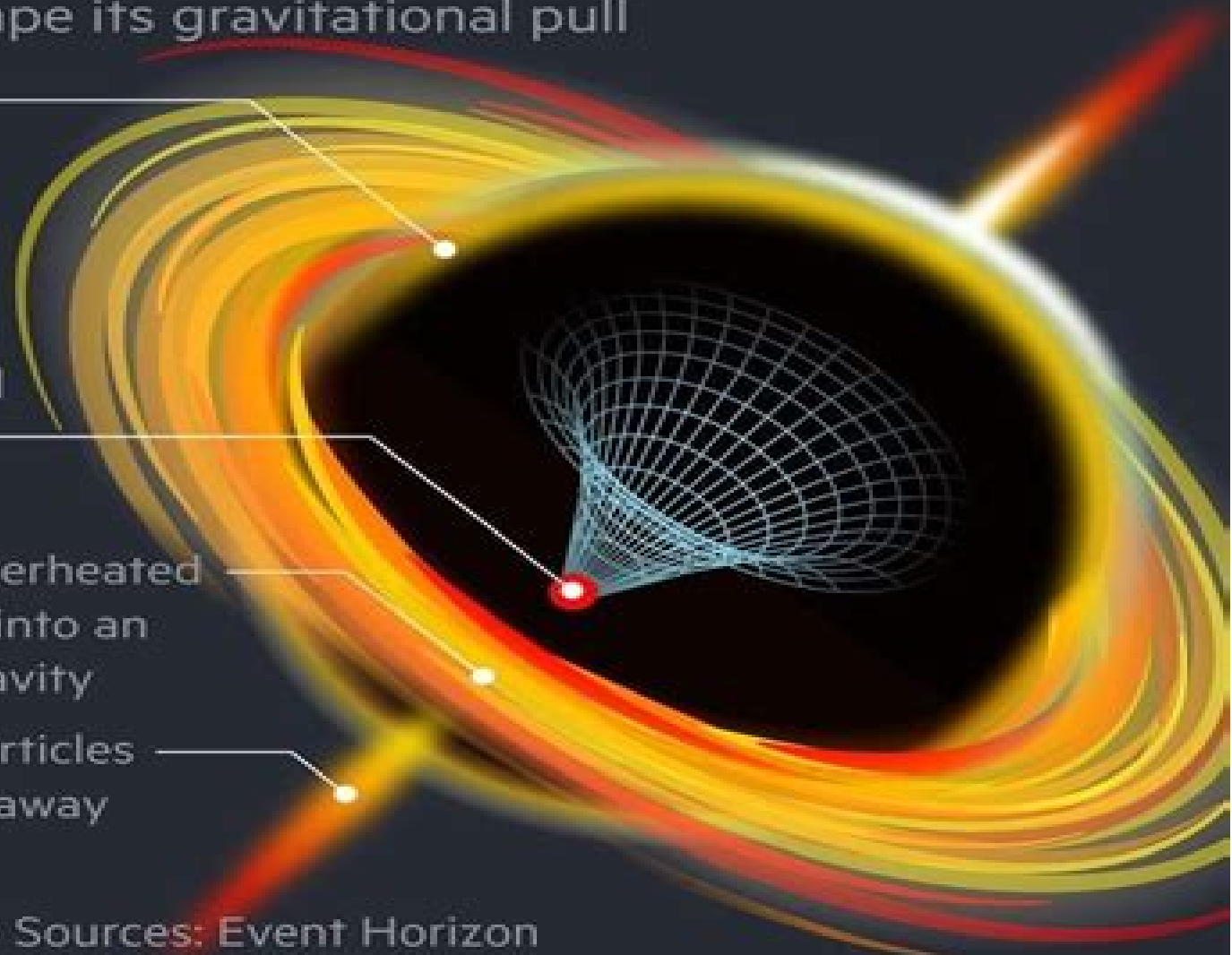
Outer boundary the scientists have been attempting to image

Singularity Central point from which nothing escapes

Accretion disc Superheated gas and dust bent into an orbiting ring by gravity

Relativistic jets Particles and radiation race away from the poles

Graphic: Ian Bott Sources: Event Horizon Telescope; ESO; Nasa; FT research



FINANCIAL TIMES

Physics Of Black Holes

Jean-Pierre Luminet



Physics Of Black Holes:

Black Hole Physics V. Frolov, I. Novikov, 2012-12-06 It is not an exaggeration to say that one of the most exciting predictions of Einstein's theory of gravitation is that there may exist black holes putative objects whose gravitational fields are so strong that no physical bodies or signals can break free of their pull and escape The proof that black holes do exist and an analysis of their properties would have a significance going far beyond astrophysics Indeed what is involved is not just the discovery of yet another even if extremely remarkable astrophysical object but a test of the correctness of our understanding of the properties of space and time in extremely strong gravitational fields Theoretical research into the properties of black holes and into the possible corollaries of the hypothesis that they exist has been carried out with special vigor since the beginning of the 1970s In addition to those specific features of black holes that are important for the interpretation of their possible astrophysical manifestations the theory has revealed a number of unexpected characteristics of physical interactions involving black holes By the middle of the 1980s a fairly detailed understanding had been achieved of the properties of the black holes their possible astrophysical manifestations and the specifics of the various physical processes involved Even though a completely reliable detection of a black hole had not yet been made at that time several objects among those scrutinized by astrophysicists were considered as strong candidates to be confirmed as being black holes Physics of Black Holes I. Novikov, V. Frolov, 2013-03-09 One of the most exciting predictions of Einstein's theory of gravitation is that there may exist black holes putative objects whose gravitational fields are so strong that no physical bodies and signals can break free of their pull and escape Even though a completely reliable discovery of a black hole has not yet been made several objects among those scrutinized by astrophysicists will very likely be confirmed as black holes The proof that they do exist and an analysis of their properties would have a significance going far beyond astrophysics Indeed what is involved is not just the discovery of yet another even if extremely remarkable astrophysical object but a test of the correctness of our understanding the properties of space and time in extremely strong gravitational fields Theoretical research into the properties of black holes and into the possible corollaries of the hypothesis that they exist has been carried out with special vigor since the beginning of the 1970s In addition to those specific features of black holes that are important for the interpretation of their possible astrophysical manifestations the theory has revealed a number of unexpected characteristics of physical interactions involving black holes By now a fairly detailed understanding has been achieved of the properties of the black holes their possible astrophysical manifestations and the specifics of the various physical processes involved Furthermore profound links were found between black hole theory and such seemingly very distant fields as thermodynamics information theory and quantum theory **Black Hole Physics** Daniel Grumiller, Mohammad Mehdi Sheikh-Jabbari, 2022-11-07 This textbook gradually introduces the reader to several topics related to black hole physics with a didactic approach It starts with the most basic black hole solution the Schwarzschild metric and discusses the basic classical properties of black hole solutions as seen

by different probes Then it reviews various theorems about black hole properties as solutions to Einstein gravity coupled to matter fields conserved charges associated with black holes and laws of black hole thermodynamics Next it elucidates semiclassical and quantum aspects of black holes which are relevant in ongoing and future research The book is enriched with many exercises and solutions to assist in the learning The textbook is designed for physics graduate students who want to start their research career in the field of black holes postdocs who recently changed their research focus towards black holes and want to get up to date on recent and current research topics advanced researchers intending to teach or learn basic and advanced aspects of black hole physics and the associated mathematical tools Besides general relativity the reader needs to be familiar with standard undergraduate physics like thermodynamics quantum mechanics and statistical mechanics Moreover familiarity with basic quantum field theory in Minkowski space is assumed The book covers the rest of the needed background material in the main text or the appendices

Introduction to Black Hole Physics Valeri P. Frolov, Andrei Zelnikov, 2011-09-23 This book is about black holes one of the most intriguing objects of modern theoretical physics and astrophysics For many years black holes have been considered as interesting solutions of the Theory of General Relativity with a number of amusing mathematical properties Now after the discovery of astrophysical black holes the Einstein gravity has become an important tool for their study This self contained textbook combines physical mathematical and astrophysical aspects of black hole theory Pedagogically presented it contains standard material on black holes as well as relatively new subjects such as the role of hidden symmetries in black hole physics and black holes in spacetimes with large extra dimensions The book will appeal to students and young scientists interested in the theory of black holes

Black Holes and Time Warps Kip S Thorne, 1994 In this masterfully written and brilliantly informed work Dr Rhorne the Feynman Professor of Theoretical Physics at Caltech leads readers through an elegant always human tapestry of interlocking themes answering the great question what principles control our universe and why do physicists think they know what they know Features an introduction by Stephen Hawking

The Little Book of Black Holes Steven S. Gubser, Frans Pretorius, 2017-09-25 Dive into a mind bending exploration of the physics of black holes Black holes predicted by Albert Einstein s general theory of relativity more than a century ago have long intrigued scientists and the public with their bizarre and fantastical properties Although Einstein understood that black holes were mathematical solutions to his equations he never accepted their physical reality a viewpoint many shared This all changed in the 1960s and 1970s when a deeper conceptual understanding of black holes developed just as new observations revealed the existence of quasars and X ray binary star systems whose mysterious properties could be explained by the presence of black holes Black holes have since been the subject of intense research and the physics governing how they behave and affect their surroundings is stranger and more mind bending than any fiction After introducing the basics of the special and general theories of relativity this book describes black holes both as astrophysical objects and theoretical laboratories in which physicists can test their understanding of gravitational quantum

and thermal physics From Schwarzschild black holes to rotating and colliding black holes and from gravitational radiation to Hawking radiation and information loss Steven Gubser and Frans Pretorius use creative thought experiments and analogies to explain their subject accessibly They also describe the decades long quest to observe the universe in gravitational waves which recently resulted in the LIGO observatories detection of the distinctive gravitational wave chirp of two colliding black holes the first direct observation of black holes existence The Little Book of Black Holes takes readers deep into the mysterious heart of the subject offering rare clarity of insight into the physics that makes black holes simple yet destructive manifestations of geometric destiny

The Shadow of Black Holes Arne Grenzebach, 2016-05-07 This book introduces an analytic method to describe the shadow of black holes As an introduction it presents a survey of the attempts to observe the shadow of galactic black holes Based on a detailed discussion of the Pleba ski Demia ski class of space times the book derives analytical formulas for the photon regions and for the boundary curve of the shadow as seen by an observer in the domain of outer communication It also analyzes how the shadow depends on the motion of the observer For all cases the photon regions and shadows are visualized for various values of the parameters Finally it considers how the analytical formulas can be used for calculating the horizontal and vertical angular diameters of the shadow and estimates values for the black holes at the centers of our Galaxy near Sgr A and of the neighboring galaxy M87

Physics of Black Holes Eleftherios Papantonopoulos, 2009-08-29 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

Black Holes Kip S. Thorne, Richard H. Price, Douglas A. MacDonald, 1986 A pedagogical introduction to the physics of black holes The membrane paradigm represents the four dimensional spacetime of the black hole s event horizon as a two dimensional membrane in three dimensional space allowing the reader to understand and compute the behavior of black holes in complex astrophysical environments

The Physics of Accretion onto Black Holes Maurizio Falanga, Tomaso Belloni, Piergiorgio Casella, Marat Gilfanov, Peter Jonker, Andrew King, 2014-10-28 Provides a comprehensive summary on the physical models and current theory of black hole accretion growth and mergers in both the supermassive and stellar mass cases This title reviews in depth research on accretion on all scales from galactic binaries to intermediate mass and supermassive black holes Possible future directions of accretion are also discussed The following main themes are

covered a historical perspective physical models of accretion onto black holes of all masses black hole fundamental parameters and accretion jets and outflows An overview and outlook on the topic is also presented This volume summarizes the status of the study of astrophysical black hole research and is aimed at astrophysicists and graduate students working in this field Originally published in Space Science Reviews Vol 183 1 4 2014 **Black Holes** Jean-Pierre Luminet,1992-08-28

Black holes are undoubtedly one of the most fascinating discoveries of modern astronomy and their description one of the most daring intellectual feats of modern times They have already become legendary forming the basis of many myths fantasies and science fiction movies Are they really the monsters which devour light and stars bottomless celestial pits into which all matter is sucked and crushed Are they an observable reality or are they just hypothetical objects from the theory of relativity In answering such questions the author takes us on a fabulous journey through space and time Dr Jean Pierre Luminet is an astronomer at Meudon Observatory in France a specialist on the subject of black holes and has also acquired a reputation for being a gifted writer and communicator In this book he makes the subject of black holes accessible to any interested reader who will need no mathematical background Quantum Black Holes Xavier Calmet,Bernard Carr,Elizabeth Winstanley,2013-11-22

Written by foremost experts this short book gives a clear description of the physics of quantum black holes The reader will learn about quantum black holes in four and higher dimensions primordial black holes the production of black holes in high energy particle collisions Hawking radiation black holes in models of low scale quantum gravity and quantum gravitational aspects of black holes *Black Holes, White Dwarfs, and Neutron Stars* Stuart L. Shapiro,Saul A. Teukolsky,2008-11-20

This self contained textbook brings together many different branches of physics e g nuclear physics solid state physics particle physics hydrodynamics relativity to analyze compact objects The latest astronomical data is assessed Over 250 exercises **Gravity, Black Holes, and the Very Early Universe** Tai L. Chow,2007-10-24

Here it is in a nutshell the history of one genius s most crucial work discoveries that were to change the face of modern physics In the early 1900s Albert Einstein formulated two theories that would forever change the landscape of physics the Special Theory of Relativity and the General Theory of Relativity Respected American academic Professor Tai Chow tells us the story of these discoveries He details the basic ideas of Einstein including his law of gravitation Deftly employing his inimitable writing style he goes on to explain the physics behind black holes weaving into his account an explanation of the structure of the universe and the science of cosmology Black Holes Explained James Negus,2018-07-15

On December 26 2015 the Laser Interferometer Gravitational Wave Observatory LIGO detected gravitational waves generated from merging black holes for the first time in human history Through an engaging easily accessible approach the origins dynamics and ultimate fate of black holes are thoroughly unraveled so that students without a scientific background can grasp complex physics theories This book supports the Next Generation Science Standards emphasis on scientific collection and analysis of data and evidence based theories by discussing the methods research universities and space

agencies use to explore black holes

Superradiance Richard Brito, Vitor Cardoso, Paolo Pani, 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

Black Hole Astrophysics David L. Meier, 2012-07-27 As a result of significant research over the past 20 years black holes are now linked to some of the most spectacular and exciting phenomena in the Universe ranging in size from those that have the same mass as stars to the super massive objects that lie at the heart of most galaxies including our own Milky Way This book first introduces the properties of simple isolated holes then adds in complications like rotation accretion radiation and magnetic fields finally arriving at a basic understanding of how these immense engines work Black Hole Astrophysics reviews our current knowledge of cosmic black holes and how they generate the most powerful observed phenomena in the Universe highlights the latest most up to date theories and discoveries in this very active area of astrophysical research demonstrates why we believe that black holes are responsible for important phenomena such as quasars microquasars and gamma ray bursts explains to the reader the nature of the violent and spectacular outflows winds and jets generated by black hole accretion

Introduction to Black Hole Astrophysics Gustavo E. Romero, Gabriela S. Vila, 2013-09-14 This book is based on the lecture notes of a one semester course on black hole astrophysics given by the author and is aimed at advanced undergraduate and graduate students with an interest in astrophysics The material included goes beyond that found in classic textbooks and presents details on astrophysical manifestations of black holes In particular jet physics and detailed accounts of objects like microquasars active galactic nuclei gamma ray bursts and ultra luminous X ray sources are covered as well as advanced topics like black holes in alternative theories of gravity The author avoids

unnecessary technicalities and to some degree the book is self contained The reader will find some basic general relativity tools in Chapter 1 The appendices provide some additional mathematical details that will be useful for further study and a guide to the bibliography on the subject *Formation and Evolution of Black Holes in the Galaxy* Gerald Edward Brown, Chang-Hwan Lee, 2003 In published papers H A Bethe and G E Brown worked out the collapse of large stars and supernova explosions They went on to evolve binaries of compact stars finding that in the standard scenario the first formed neutron star always went into a black hole in common envelope evolution C H Lee joined them in the study of black hole binaries and gamma ray bursts They found the black holes to be the fossils of the gamma ray bursts From their properties they could reconstruct features of the burst and of the accompanying hypernova explosions This invaluable book contains 23 papers on astrophysics chiefly on compact objects written over 23 years The papers are accompanied by illuminating commentary In addition there is an appendix on kaon condensation which the editors believe to be relevant to the equation of state in neutron stars and to explain why black holes are formed at relatively low masses *What Does a Black Hole Look Like?* Charles D. Bailyn, 2014-08-31 A sophisticated introduction to how astronomers identify observe and understand black holes Emitting no radiation or any other kind of information black holes mark the edge of the universe both physically and in our scientific understanding Yet astronomers have found clear evidence for the existence of black holes employing the same tools and techniques used to explore other celestial objects In this sophisticated introduction leading astronomer Charles Bailyn goes behind the theory and physics of black holes to describe how astronomers are observing these enigmatic objects and developing a remarkably detailed picture of what they look like and how they interact with their surroundings Accessible to undergraduates and others with some knowledge of introductory college level physics this book presents the techniques used to identify and measure the mass and spin of celestial black holes These key measurements demonstrate the existence of two kinds of black holes those with masses a few times that of a typical star and those with masses comparable to whole galaxies supermassive black holes The book provides a detailed account of the nature formation and growth of both kinds of black holes The book also describes the possibility of observing theoretically predicted phenomena such as gravitational waves wormholes and Hawking radiation A cutting edge introduction to a subject that was once on the border between physics and science fiction this book shows how black holes are becoming routine objects of empirical scientific study

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