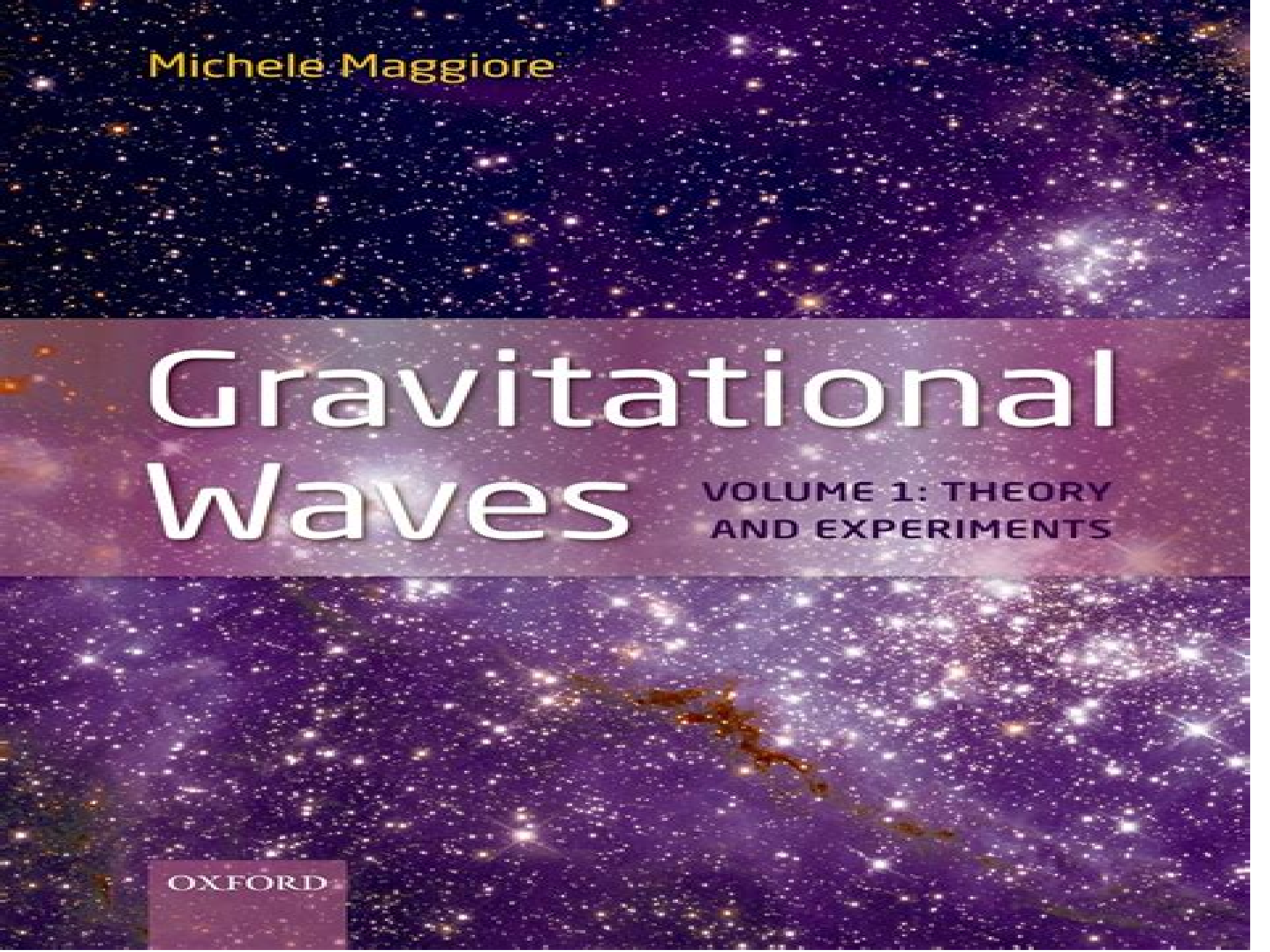




Michele Maggiore

# Gravitational Waves

VOLUME 1: THEORY  
AND EXPERIMENTS

OXFORD

# Gravitational Waves Volume 1 Theory And Experiments

**Carlo Nicola Colacino**



## **Gravitational Waves Volume 1 Theory And Experiments:**

**Gravitational Waves** Michele Maggiore, 2008 The two volumes of Gravitational Waves provide a comprehensive and detailed account of the physics of gravitational waves Volume 2 discusses what can be learned from gravitational waves in astrophysics and in cosmology by systematising a large body of theoretical developments that have taken place over the last decades Gravitational Waves Michele Maggiore, 2008 *Gravitational Waves, Pack: Volumes 1 and 2* Michele Maggiore, 2018-05-29 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

**Theory and Experiment in Gravitational Physics** Clifford M. Will, 2018-09-27 The 2015 centenary of the publication of Einstein's general theory of relativity and the first detection of gravitational waves have focused renewed attention on the question of whether Einstein was right This review of experimental gravity provides a detailed survey of the intensive testing of Einstein's theory of gravity including tests in the emerging strong field dynamical regime It discusses the theoretical frameworks needed to analyze gravitational theories and interpret experiments Completely revised and updated this new edition features coverage of new alternative theories of gravity a unified treatment of gravitational radiation and the implications of the latest binary pulsar observations It spans the earliest tests involving the Solar System to the latest tests using gravitational waves detected from merging black holes and neutron stars It is a comprehensive reference for researchers and graduate students working in general relativity cosmology particle physics and astrophysics

**Fundamentals Of Interferometric Gravitational Wave Detectors (Second Edition)** Peter R. Saulson, 2017-02-16 The content of the Saulson'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 Physics 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

*Nanohertz Gravitational Wave Astronomy* Stephen R. Taylor, 2021-11-23 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, 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 *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

**Gravitational Waves** Michele Maggiore, 2018

**Gravitational Wave Science with Machine Learning** Elena Cuoco, 2025-04-11

This book highlights the state of the art of machine learning applied to the science of gravitational waves. The main topics of the book range from the search for astrophysical gravitational wave signals to noise suppression techniques and control systems using machine learning based algorithms. During the four years of work in the COST Action CA17137 A network for Gravitational Waves Geophysics and Machine Learning G2net the collaboration produced several original publications as well as tutorials and lectures in the training schools we organized. The book encapsulates the immense amount of finding and achievements. It is a timely reference for young researchers approaching the analysis of data from gravitational wave experiments with alternative approaches based on the use of artificial intelligence techniques.

**Black Hole Formation and Growth** Tiziana Di Matteo, Andrew King, Neil J. Cornish, 2019-10-31

The ultimate proofs that black holes exist have been obtained very recently thanks to the detection of gravitational waves from their coalescence and due to material orbiting at a distance of some gravitational radii imaged by optical interferometry or X ray reverberation mapping. This book provides three comprehensive and up to date reviews covering the gravitational wave breakthrough our understanding of accretion and feedback in supermassive black holes and the relevance of black holes for the Universe since the Big Bang. Neil J Cornish presents gravitational wave emission from black hole mergers and the physics of detection. Andrew King reviews the physics of accretion on to supermassive black holes and their feedback on host galaxies. Tiziana Di Matteo addresses our understanding of black hole formation at cosmic dawn, the emergence of the first quasars, black hole merging and structure formation. The topics covered by the 48th Saas Fee Course provide a broad overview of the importance of black holes in modern astrophysics.

**Globular Cluster Binaries and Gravitational Wave Parameter Estimation** Carl-Johan Haster, 2017-07-27

This thesis presents valuable contributions to several aspects of the rapidly growing field of gravitational wave astrophysics. The potential sources of gravitational waves in globular clusters are analyzed using sophisticated dynamics simulations involving intermediate mass black holes and including for the first time high order post Newtonian corrections to the equations of motion. The thesis further demonstrates our ability to accurately measure the parameters of the sources involved in intermediate mass ratio inspirals of stellar mass compact objects into hundred solar mass black holes. Lastly it proposes new techniques for the computationally efficient inference on gravitational waves. On 14 September 2015 the LIGO observatory reported the first direct detection of gravitational waves from the merger of a pair of black holes. For a brief fraction of a second the power emitted by this merger exceeded the combined output of all stars in the visible universe. This has since been followed by another confirmed detection and a third candidate binary black hole merger. These detections heralded the birth of an exciting new field: gravitational wave astrophysics.

**Physics of Binary Star Evolution** Thomas M. Tauris, Edward P.J. van den Heuvel, 2023-06-20

A graduate level textbook

on the astrophysics of binary star systems and their evolution Physics of Binary Star Evolution is an up to date textbook on the astrophysics and evolution of binary star systems Theoretical astrophysicists Thomas Tauris and Edward van den Heuvel cover a wide range of phenomena and processes including mass transfer and ejection common envelopes novae and supernovae X ray binaries millisecond radio pulsars and gravitational wave GW sources and their links to stellar evolution The authors walk through the observed properties and evolution of different types of binaries with special emphasis on those containing compact objects neutron stars black holes and white dwarfs Attention is given to the formation mechanisms of GW sources merging double neutron stars and black holes as well as ultra compact GW binaries hosting white dwarfs and to the progenitors of these sources and how they are observed with radio telescopes X ray satellites and GW detectors LIGO Virgo KAGRA Einstein Telescope Cosmic Explorer and LISA Supported by illustrations equations and exercises Physics of Binary Star Evolution combines theory and observations to guide readers through the wonders of a field that will play a central role in modern astrophysics for decades to come 465 equations 47 tables and 350 figures More than 80 exercises analytical numerical and computational Over 2 500 extensive up to date references

**New Frontiers in GRMHD Simulations**  
Cosimo Bambi, Yosuke Mizuno, Swarnim Shashank, Feng Yuan, 2025-03-10 This book offers an updated comprehensive review of the rapidly expanding field of GRMHD simulations In Part I it reviews the basic equations for GRMHD simulations and for numerical relativity Part II describes public codes for GRMHD simulations Part III is devoted to accretion processes onto compact objects in the non self gravitating fluid approximation Part IV reviews the state of the art of GRMHD simulations with self gravitating fluids This book represents both a valuable book for graduate students and important reference resource for researchers in the field

*De-noising of Gravitational-Wave Data* Pablo Barneo, 2024-03-11 Since the first experimental evidence for the existence of gravitational waves in 2015 the amount of data in this scientific area has increased enormously There has also been a great deal of interest in the scientific community in gravitational waves The interferometers used to capture these waves need to achieve a high level of instrumental sensitivity to be able to detect and analyse the weak signals emitted by both distant sources of intrinsically high intensity and nearby sources of much lower intensity High sensitivity is often accompanied by high levels of noise that difficult data analysis In nowadays interferometers large amounts of data are recorded with a high percentage of noise from which we attempt to extract the possible gravitational waves buried therein In this dissertation we propose to use a denoising method based on the minimisation of the total variance of the time series that constitute the data Known as the ROF method it assumes that the largest contribution to the total variance of a function comes from noise In this way a minimisation of this variance should lead to a drastic reduction in the presence of noise This denoising procedure helps to improve the detection and data quality of gravitational wave analysis We have implemented two ROF based denoising algorithms in a commonly used gravitational wave analysis software package The analysis package is known as coherent WaveBurst cWB and uses the excess energy from the coherence between data from two or more

interferometers to find gravitational waves The denoising methods are the one step regularised ROF rROF and the iterative rROF procedure irROF We have tested both methods using events from the gravitational wave catalogue of the first three observing periods of the LIGO Virgo KAGRA scientific collaboration These events named GW1501914 GW151226 GW170817 and GW190521 comprise different wave morphologies of compact binary systems injected at different noise quality levels

*Broadband Quantum Noise Reduction in Advanced Virgo Plus* Eleonora Polini, 2025-09-12 This book presents the first implementation of frequency dependent squeezing in the Virgo gravitational wave detector a technique that reduces quantum noise across the entire detection band By lowering noise it enhances Virgo's ability to observe the universe It provides a detailed account of the experimental optical system spanning hundreds of meters and the measurement campaign that led to the first observation of frequency dependent squeezing with ellipse rotation occurring at the target frequency of a few tens of Hz Additionally the book covers the characterization and commissioning of a new Output Mode Cleaner cavity in Virgo to minimize optical losses on squeezed states Finally it examines the impact of stray light noise at low frequencies and explores mitigation strategies to improve detector sensitivity

Probabilistic Models of Cosmic Backgrounds Anatoliy Malyarenko, 2024-06-30 Combining research methods from various areas of mathematics and physics Probabilistic Models of Cosmic Backgrounds describes the isotropic random sections of certain fiber bundles and their applications to creating rigorous mathematical models of both discovered and hypothetical cosmic backgrounds Previously scattered and hard to find mathematical and physical theories have been assembled from numerous textbooks monographs and research papers and explained from different or even unexpected points of view This consists of both classical and newly discovered results necessary for understanding a sophisticated problem of modelling cosmic backgrounds The book contains a comprehensive description of mathematical and physical aspects of cosmic backgrounds with a clear focus on examples and explicit calculations Its reader will bridge the gap of misunderstanding between the specialists in various theoretical and applied areas who speak different scientific languages The audience of the book consists of scholars students and professional researchers A scholar will find basic material for starting their own research A student will use the book as supplementary material for various courses and modules A professional mathematician will find a description of several physical phenomena at the rigorous mathematical level A professional physicist will discover mathematical foundations for well known physical theories

**Primordial Black Holes** Christian Byrnes, Gabriele Franciolini, Tomohiro Harada, Paolo Pani, Misao Sasaki, 2025-04-30 Primordial black holes PBHs were proposed more than 50 years ago as black holes possibly formed across a vast mass range in the early universe They represent a unique probe to access the primordial universe and cosmological inflation Furthermore in certain mass ranges they could comprise the entirety of the dark matter seed supermassive black holes at high redshift be responsible for some gravitational wave events detected so far and be novel gravitational wave sources detectable with future instruments However detecting PBHs has proved to be extremely challenging and extensive

research focused on setting a variety of constraints on the fraction of dark matter composed by these objects This book highlights an up to date comprehensive overview on this subject including pedagogical details on the PBH formation scenarios cosmological evolution astrophysical implications connections with gravitational wave astronomy and critical discussion of the latest and future constraints At variance with all existing reviews on this subject this book addresses graduate students and researchers not necessarily familiar with all areas of the topic providing details on important key results rather than collecting and reviewing the latest literature The topic is naturally interdisciplinary and connects areas as diverse as cosmology particle physics gravitational wave astronomy and numerical simulations To reflect this diversity the book includes 25 contributions from key researchers working in these different areas It provides a unique reference both to approach the topic for the first time and to learn a specific specialized sub area

Detecting the Stochastic Gravitational-Wave Background Carlo Nicola Colacino, 2017-12-20 The stochastic gravitational wave background SGWB is by far the most difficult source of gravitational radiation detect At the same time it is the most interesting and intriguing one This book describes the initial detection of the SGWB and describes the underlying mathematics behind one of the most amazing discoveries of the 21st century On the experimental side it would mean that interferometric gravitational wave detectors work even better than expected On the observational side such a detection could give us information about the very early Universe information that could not be obtained otherwise Even negative results and improved upper bounds could put constraints on many cosmological and particle physics models

**Fifteenth Marcel Grossmann Meeting, The: On Recent Developments In Theoretical And Experimental General Relativity, Astrophysics, And Relativistic Field Theories - Proceedings Of The Mg15 Meeting On General Relativity (In 3 Volumes)** Elia S Battistelli, Robert T Jantzen, Remo Ruffini, 2022-05-10 The three volumes of the proceedings of MG15 give a broad view of all aspects of gravitational physics and astrophysics from mathematical issues to recent observations and experiments The scientific program of the meeting included 40 morning plenary talks over 6 days 5 evening popular talks and nearly 100 parallel sessions on 71 topics spread over 4 afternoons These proceedings are a representative sample of the very many oral and poster presentations made at the meeting Part A contains plenary and review articles and the contributions from some parallel sessions while Parts B and C consist of those from the remaining parallel sessions The contents range from the mathematical foundations of classical and quantum gravitational theories including recent developments in string theory to precision tests of general relativity including progress towards the detection of gravitational waves and from supernova cosmology to relativistic astrophysics including topics such as gamma ray bursts black hole physics both in our galaxy and in active galactic nuclei in other galaxies and neutron star pulsar and white dwarf astrophysics Parallel sessions touch on dark matter neutrinos X ray sources astrophysical black holes neutron stars white dwarfs binary systems radiative transfer accretion disks quasars gamma ray bursts supernovas alternative gravitational theories perturbations of collapsed objects

analog models black hole thermodynamics numerical relativity gravitational lensing large scale structure observational cosmology early universe models and cosmic microwave background anisotropies inhomogeneous cosmology inflation global structure singularities chaos Einstein Maxwell systems wormholes exact solutions of Einstein's equations gravitational waves gravitational wave detectors and data analysis precision gravitational measurements quantum gravity and loop quantum gravity quantum cosmology strings and branes self gravitating systems gamma ray astronomy cosmic rays and the history of general relativity

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