

# Gravitational Collapse and Spacetime Singularities

PANKAJ S. JOSHI

CAMBRIDGE MONOGRAPHS  
ON MATHEMATICAL PHYSICS

# Gravitational Collapse And Spacetime Singularities Cambridge Monographs On Mathematical Physics

**Demetrios Christodoulou**



## **Gravitational Collapse And Spacetime Singularities Cambridge Monographs On Mathematical Physics:**

**Gravitational Collapse and Spacetime Singularities** Pankaj S. Joshi, 2007-12-13 Physical phenomena in astrophysics and cosmology involve gravitational collapse in a fundamental way The final fate of a massive star when it collapses under its own gravity at the end of its life cycle is one of the most important questions in gravitation theory and relativistic astrophysics and is the foundation of black hole physics General relativity predicts that continual gravitational collapse gives rise to a space time singularity Quantum gravity may take over in such regimes to resolve the classical space time singularity This book investigates these issues and shows how the visible ultra dense regions arise naturally and generically as an outcome of dynamical gravitational collapse It will be of interest to graduate students and academic researchers in gravitation physics fundamental physics astrophysics and cosmology It includes a detailed review of research into gravitational collapse and several examples of collapse models are investigated in detail **New Frontiers in**

**Gravitational Collapse and Spacetime Singularities** Daniele Malafarina, Pankaj S. Joshi, 2024-05-02 The book collects a series of articles to review the advances that have been made in the field of gravitational collapse in general relativity and alternative theories of gravity in the past few years Many approaches to black hole and singularity formation in general relativity and beyond have been proposed over the last few decades The importance of collapse models is that they provide natural thought experiments where to test the behavior and properties of a variety of approaches to general relativity and its implications for ultra compact objects in the universe **Regular Black Holes** Cosimo Bambi, 2023-07-06 Black holes are

one of the most fascinating predictions of general relativity They are the natural product of the complete gravitational collapse of matter and today we have a body of observational evidence supporting the existence of black holes in the Universe However general relativity predicts that at the center of black holes there are spacetime singularities where predictability is lost and standard physics breaks down It is widely believed that spacetime singularities are a symptom of the limitations of general relativity and must be solved within a theory of quantum gravity Since we do not have yet any mature and reliable candidate for a quantum gravity theory researchers have studied toy models of singularity free black holes and of singularity free gravitational collapses in order to explore possible implications of the yet unknown theory of quantum gravity This book reviews all main models of regular black holes and non singular gravitational collapses proposed in the literature and discuss the theoretical and observational implications of these scenarios **The Formation of Black Holes in**

**General Relativity** Demetrios Christodoulou, 2009 In 1965 Penrose introduced the fundamental concept of a trapped surface on the basis of which he proved a theorem which asserts that a spacetime containing such a surface must come to an end The presence of a trapped surface implies moreover that there is a region of spacetime the black hole which is inaccessible to observation from infinity Since that time a major challenge has been to find out how trapped surfaces actually form by analyzing the dynamics of gravitational collapse The present monograph achieves this aim by establishing the formation of

trapped surfaces in pure general relativity through the focusing of gravitational waves The theorems proved in this monograph constitute the first foray into the long time dynamics of general relativity in the large that is when the initial data are no longer confined to a suitable neighborhood of trivial data The main new method the short pulse method applies to general systems of Euler Lagrange equations of hyperbolic type and provides the means to tackle problems which have hitherto seemed unapproachable This monograph will be of interest to people working in general relativity geometric analysis and partial differential equations

**The Princeton Companion to Mathematics** Timothy Gowers, June Barrow-Green, Imre Leader, 2010-07-18 The ultimate mathematics reference book This is a one of a kind reference for anyone with a serious interest in mathematics Edited by Timothy Gowers a recipient of the Fields Medal it presents nearly two hundred entries written especially for this book by some of the world's leading mathematicians that introduce basic mathematical tools and vocabulary trace the development of modern mathematics explain essential terms and concepts examine core ideas in major areas of mathematics describe the achievements of scores of famous mathematicians explore the impact of mathematics on other disciplines such as biology finance and music and much much more Unparalleled in its depth of coverage The Princeton Companion to Mathematics surveys the most active and exciting branches of pure mathematics Accessible in style this is an indispensable resource for undergraduate and graduate students in mathematics as well as for researchers and scholars seeking to understand areas outside their specialties Features nearly 200 entries organized thematically and written by an international team of distinguished contributors Presents major ideas and branches of pure mathematics in a clear accessible style Defines and explains important mathematical concepts methods theorems and open problems Introduces the language of mathematics and the goals of mathematical research Covers number theory algebra analysis geometry logic probability and more Traces the history and development of modern mathematics Profiles more than ninety five mathematicians who influenced those working today Explores the influence of mathematics on other disciplines Includes bibliographies cross references and a comprehensive index Contributors include Graham Allan Noga Alon George Andrews Tom Archibald Sir Michael Atiyah David Aubin Joan Bagaria Keith Ball June Barrow Green Alan Beardon David D Ben Zvi Vitaly Bergelson Nicholas Bingham B la Bollob s Henk Bos Bodil Branner Martin R Bridson John P Burgess Kevin Buzzard Peter J Cameron Jean Luc Chabert Eugenia Cheng Clifford C Cocks Alain Connes Leo Corry Wolfgang Coy Tony Crilly Serafina Cuomo Mihalis Dafermos Partha Dasgupta Ingrid Daubechies Joseph W Dauben John W Dawson Jr Francois de Gandt Persi Diaconis Jordan S Ellenberg Lawrence C Evans Florence Fasanelli Anita Burdman Feferman Solomon Feferman Charles Fefferman Della Fenster Jos Ferreir s David Fisher Terry Gannon A Gardiner Charles C Gillispie Oded Goldreich Catherine Goldstein Fernando Q Gouv a Timothy Gowers Andrew Granville Ivor Grattan Guinness Jeremy Gray Ben Green Ian Grojnowski Niccol Guicciardini Michael Harris Ulf Hashagen Nigel Higson Andrew Hodges F E A Johnson Mark Joshi Kiran S Kedlaya Frank Kelly Sergiu Klainerman Jon Kleinberg Israel Kleiner Jacek Klinowski Eberhard Knobloch J nos Koll r T W K

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 Dominic Welsh Avi Wigderson Herbert Wilf David Wilkins B Yandell Eric Zaslow and Doron Zeilberger     *The singularities  
 as ontological limits of the general relativity* Nicolae Sfetcu,2019-01-31 ESSAYS Collection The singularities from the general  
 relativity resulting by solving Einstein s equations were and still are the subject of many scientific debates Are there  
 singularities in spacetime or not Big Bang was an initial singularity If singularities exist what is their ontology Is the general  
 theory of relativity a theory that has shown its limits in this case In this essay I argue that there are singularities and the  
 general theory of relativity as any other scientific theory at present is not valid for singularities But that does not mean as  
 some scientists think that it must be regarded as being obsolete After a brief presentation of the specific aspects of  
 Newtonian classical theory and the special theory of relativity and a brief presentation of the general theory of relativity the  
 chapter Ontology of General Relativity presents the ontological aspects of general relativity The next chapter Singularities is  
 dedicated to the presentation of the singularities resulting in general relativity the specific aspects of the black holes and the  
 event horizon including the Big Bang debate as original singularity and arguments for the existence of the singularities In  
 Singularity Ontology I am talking about the possibilities of ontological framing of singularities in general and black holes in  
 particular about the hole argument highlighted by Einstein and the arguments presented by scientists that there are no  
 singularities and therefore that the general theory of relativity is in deadlock In Conclusions I outline and summarize briefly  
 the arguments that support my above views CONTENTS Abstract Introduction Classical Theory and Special Relativity  
 General Relativity GR 1 Ontology of General Relativity 2 Singularities Black Holes Event Horizon Big Bang Are there  
 Singularities 3 Ontology of Singularities Ontology of black holes The hole argument There are no singularities Conclusions  
 Notes Bibliography     **Discrete Holography: Through the Quantum Information Looking-Glass** Pablo  
 Basteiro,2025-07-21 How can we reconcile general relativity with quantum mechanics One promising approach is the  
 holographic principle which posits that quantum gravity can be described by a lower dimensional theory without gravity This  
 book advances the field of discrete holography by building models on discretizations of hyperbolic space extending the AdS  
 CFT correspondence and enabling experimental tests of holographic predictions The first part develops discrete bulk models  
 on hyperbolic tilings exploring scalar field instability and correlation functions and proposes electric circuits as experimental

platforms The second part constructs boundary theories as disordered spin chains and analyzes their entanglement via tensor networks The final part investigates quantum information measures circuit complexity geometric quantum discord and operator algebras to probe black hole properties in holographic dualities This work uncovers new insights into holography and bridges theoretical concepts with experimental realizations      *Seminar on Differential Geometry* Shing-Tung

Yau, Institute for Advanced Study (Princeton, N.J.), 1982-03-21 This collection of papers constitutes a wide ranging survey of recent developments in differential geometry and its interactions with other fields especially partial differential equations and mathematical physics This area of mathematics was the subject of a special program at the Institute for Advanced Study in Princeton during the academic year 1979-1980 the papers in this volume were contributed by the speakers in the sequence of seminars organized by Shing Tung Yau for this program Both survey articles and articles presenting new results are included The articles on differential geometry and partial differential equations include a general survey article by the editor on the relationship of the two fields and more specialized articles on topics including harmonic mappings isoperimetric and Poincaré inequalities metrics with specified curvature properties the Monge-Ampère equation  $L^2$  harmonic forms and cohomology manifolds of positive curvature isometric embedding and Krausman manifolds and metrics The articles on differential geometry and mathematical physics cover such topics as renormalization instantons gauge fields and the Yang-Mills equation nonlinear evolution equations incompleteness of space-times black holes and quantum gravity A feature of special interest is the inclusion of a list of more than one hundred unsolved research problems compiled by the editor with comments and bibliographical information      **Supersymmetric Solitons** M. Shifman, A. Yung, 2023-07-27 This book

summarizes major advances in critical solitons in supersymmetric theories and their implications for understanding basic dynamical regularities of non-supersymmetric theories First published in 2009 this title has been reissued as an Open Access publication on Cambridge Core      *Quantum Field Theory in Curved Spacetime* Leonard Parker, David Toms, 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

**Perspectives In Scalar Curvature (In 2 Volumes)** Mikhail L Gromov, H Blaine Lawson, Jr., 2022-12-19 Volume I contains a long article by Misha Gromov based on his many years of involvement in this subject It came from lectures

delivered in Spring 2019 at IHES There is some background given Many topics in the field are presented and many open problems are discussed One intriguing point here is the crucial role played by two seemingly unrelated analytic means index theory of Dirac operators and geometric measure theory Very recently there have been some real breakthroughs in the field Volume I has several survey articles written by people who were responsible for these results For Volume II many people in areas of mathematics and physics whose work is somehow related to scalar curvature were asked to write about this in any way they pleased This gives rise to a wonderful collection of articles some with very broad and historical views others which discussed specific fascinating subjects These two books give a rich and powerful view of one of geometry's very appealing sides

*Progress in Lorentzian Geometry* Waldemar Barrera, Jónatan Herrera, Juan Pablo Navarrete, Matias Navarro, Oscar Palmas, Didier A. Solis, 2025-09-30 This proceedings volume gathers selected revised papers presented at the XI International Meeting on Lorentzian Geometry GeLoMer 2024 held at the Autonomous University of Yucatán Mexico from January 29 to February 2 2024 Lorentzian geometry provides the mathematical foundation for Einstein's theory of relativity It incorporates aspects from different branches of mathematics such as differential geometry partial differential equations and mathematical analysis to name a few This volume includes surveys describing the state of the art in specific areas and a selection of the most relevant results presented at the conference which is seen as a benchmark for those working in Lorentz geometry due to its relevance Given its scope the book will be of interest to both young and experienced mathematicians and physicists whose research involves general relativity and semi Riemannian geometry

Conformal Methods in General Relativity Juan A. Valiente Kroon, 2023-02-09 This 2016 volume now reissued as OA shows how conformal methods can be used to study Einstein's theory of gravity

**The Far-future Universe** George Francis Rayner Ellis, 2002 Will our universe continue to expand 100 billion years from now Does human life and all intelligence inevitably come to an end as the universe evolves Could our present space be converted catastrophically into a new kind of space governed by different physical laws Can we construct a theology of the future universe Would the continuation of the universe for eternity be a good thing The Far Future Universe presents eighteen provocative essays offering speculations on various scenarios for the future from the perspectives of cosmology physics biology humanity and theology Other contributors consider global time artificial intelligence religious ideas about the end of the world and the nature of existence Stimulating challenging and exciting these visions of the far future are a starting point for further reflection and speculation

**Quantum Gravity and the Functional Renormalization Group** Martin Reuter, Frank Saueressig, 2019-01-03 A self contained pedagogical introduction to asymptotic safety and the functional renormalization group in quantum gravity for graduate students and researchers

**Hamiltonian Mechanics of Gauge Systems** Lev V. Prokhorov, Sergei V. Shabanov, 2011-09-22 The principles of gauge symmetry and quantization are fundamental to modern understanding of the laws of electromagnetism weak and strong subatomic forces and the theory of general relativity Ideal for graduate students and researchers in theoretical and

mathematical physics this unique book provides a systematic introduction to Hamiltonian mechanics of systems with gauge symmetry The book reveals how gauge symmetry may lead to a non trivial geometry of the physical phase space and studies its effect on quantum dynamics by path integral methods It also covers aspects of Hamiltonian path integral formalism in detail along with a number of related topics such as the theory of canonical transformations on phase space supermanifolds non commutativity of canonical quantization and elimination of non physical variables The discussion is accompanied by numerous detailed examples of dynamical models with gauge symmetries clearly illustrating the key concepts

**Gravity and Strings** Tomás Ortín, 2015-03-26 Self contained and comprehensive this definitive new edition of Gravity and Strings is a unique resource for graduate students and researchers in theoretical physics From basic differential geometry through to the construction and study of black hole and black brane solutions in quantum gravity via all the intermediate stages this book provides a complete overview of the intersection of gravity supergravity and superstrings Now fully revised this second edition covers an extensive array of topics including new material on non linear electric magnetic duality the electric tensor formalism matter coupled supergravity supersymmetric solutions the geometries of scalar manifolds appearing in 4 and 5 dimensional supergravities and much more Covering reviews of important solutions and numerous solution generating techniques and accompanied by an exhaustive index and bibliography this is an exceptional reference work

*Nonequilibrium Quantum Field Theory* Esteban A. Calzetta, Bei-Lok B. Hu, 2023-02-09 This 2008 book reissued as OA captures the essence of nonequilibrium quantum field theory graduate students and researchers

**Rotating Relativistic Stars** John L. Friedman, Nikolaos Stergioulas, 2013-02-11 This volume pulls together more than forty years of research to provide graduate students and researchers in astrophysics gravitational physics and astronomy with the first self contained treatment of the structure stability and oscillations of rotating neutron stars

*Particle Physics of Brane Worlds and Extra Dimensions* Sreerup Raychaudhuri, K. Sridhar, 2016-04-25 A comprehensive account of new models of extra dimensions which form an important part of present day high energy physics



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