

Spacetime Singularities and Invariance

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1 Introduction

Spacetime singularities are an important topic in general relativity and in cosmology, but understanding their philosophical significance is rather a side-issue in contemporary debates in philosophy of physics. The prevailing attitude still seems to be that singularities constitute a breakdown of physical laws.¹ A notable exception to this rather unfortunate state of affairs is John Earman's book, *Bangs, Crunches, Whimpers, and Shrieks* (Earman, 1995), published 20 years ago, focused on issues related to the definition, proper characterization, and existence of singularities, as well as on several problems and hypotheses that they are thought to have given rise to. Proposing a tolerant attitude towards singularities, Earman discusses cosmic censorship, supertasks, and the horizon problem, among other issues. What we discuss in the present paper is a novel approach to singularities, based on a recent extension of general relativity that shows why singularities do not actually constitute a breakdown of physical laws: it is not only the case that physical laws are valid, but they also remain invariant at singularities (Stoica, 2013). We are interested here in describing this kind of invariance, as well as in drawing its consequences for our understanding of equivalence in general relativity. In particular, adopting a distinction recently introduced by Dennis Dieks (Dieks, 2006), we point out that the difference between the metrics at singularities and those outside of singularities is factual, rather than nomological, and that this justifies the extension of the principle of equivalence to singularities.

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¹See, e.g., this remark in a recent collection on the philosophy of general relativity: "If you think you have a singularity, then you can't use it in a physical model. You don't know how to include such an object in a physical system, either as the outcome of gravitational collapse or as an object that might affect other objects with its gravitational field. [...] you are paralyzed by incomprehension." (Schutz, 2012)

Spacetime And Singularities An Introduction

**Kingman Cheung, John Francis
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Spacetime And Singularities An Introduction:

Spacetime and Singularities Gregory L. Naber, 1988 An elementary introduction to the geometrical methods and notions used in special and general relativity Emphasizes the ideas concerned with structure of space time that play a role in Penrose Hawking singularity theorems 100 Years Of Relativity: Space-time Structure - Einstein And Beyond Abhay Ashtekar, 2005-11-22 Thanks to Einstein's relativity theories our notions of space and time underwent profound revisions about a 100 years ago The resulting interplay between geometry and physics has dominated all of fundamental physics since then This volume contains contributions from leading researchers worldwide who have thought deeply about the nature and consequences of this interplay The articles take a long range view of the subject and distill the most important advances in broad terms making them easily accessible to non specialists The first part is devoted to a summary of how relativity theories were born J Stachel The second part discusses the most dramatic ramifications of general relativity such as black holes P Chrusciel and R Price space time singularities H Nicolai and A Rendall gravitational waves P Laguna and P Saulson the large scale structure of the cosmos T Padmanabhan experimental status of this theory C Will as well as its practical application to the GPS system N Ashby The last part looks beyond Einstein and provides glimpses into what is in store for us in the 21st century Contributions here include summaries of radical changes in the notions of space and time that are emerging from quantum field theory in curved space times Ford string theory T Banks loop quantum gravity A Ashtekar quantum cosmology M Bojowald discrete approaches Dowker Gambini and Pullin and twistor theory R Penrose **Reasonable Faith (3rd edition)** William Lane Craig, 2008-06-09 Perfect as a textbook yet excellent for lay readers this updated edition builds a positive case for Christianity by applying the latest thought to core theological themes J Gresham Machen once said False ideas are the greatest obstacles to the reception of the gospel which makes apologetics that much more important Wanting to engage not just academics and pastors but Christian laypeople and seekers William Lane Craig has revised and updated key sections in this third edition of his classic text to reflect the latest work in astrophysics philosophy probability calculus the arguments for the existence of God and Reformed epistemology His approach that of positive apologetics gives careful attention to crucial questions and concerns including the relationship of faith and reason the existence of God the problems of historical knowledge and miracles the personal claims of Christ and the historicity of the resurrection of Jesus He shows that there is good reason to think Christianity is true As Craig says If you have a sound and persuasive case for Christianity you don't have to become an expert in comparative religions and Christian cults A positive justification of the Christian faith automatically overwhelms all competing world views lacking an equally strong case **The New Mormon Challenge** Zondervan, 2010-12-21 Current facts about Mormonism Over 11 million members Over 60 000 full time missionaries more than any other single missionary sending organization in the world More than 310 000 converts annually As many as eighty percent of converts come from Protestant backgrounds In Mormon circles the saying is We baptize a Baptist church every

week Within fifteen years the numbers of missionaries and converts will roughly double Within eighty years with adherents exceeding 267 million Mormonism could become the first world religion to arise since Islam You may know the statistics What you probably don't know are the advances the Church of Jesus Christ of Latter-day Saints LDS is making in apologetics and academic respectability With superb training Mormon scholars outclass many of their opponents Arguments against Mormon claims are increasingly refuted as outdated misinformed or poorly argued The New Mormon Challenge is a response to the burgeoning challenge of scholarly Mormon apologetics Written by a team of respected Christian scholars it is free of caricature sensationalism and diatribe The respectful tone and responsible rigorous yet readable scholarship set this book in a class of its own It offers freshly researched and well documented rebuttals of Mormon truth claims Most of the chapter topics have never been addressed and the criticisms and arguments are almost entirely new But The New Mormon Challenge does not merely challenge Mormon beliefs it offers the LDS Church and her members ways to move forward The New Mormon Challenge will help you understand the intellectual appeal of Mormonism and it will reveal many of the fundamental weaknesses of the Mormon worldview Whether you are sharing the gospel with Mormons or are investigating Mormonism for yourself this book will help you accurately understand Mormonism and see the superiority of the historic Christian faith Outstanding scholarship and sound methodology make this an ideal textbook The biblical historical scientific philosophical and theological discussions are fascinating and will appeal to Christians and Mormons alike Exemplifying Christian scholarship at its best The New Mormon Challenge pioneers a new genre of literature on Mormonism The Editors Francis J Beckwith Carl Mosser and Paul Owen are respected authorities on the Church of Jesus Christ of Latter-day Saints and the authors of various books and significant articles on Mormonism With contributors including such respected scholars as Craig L Blomberg William Lane Craig J P Moreland and others The New Mormon Challenge is as Richard Mouw states in his foreword an important event for both Protestant evangelicals and Mormons that models to the evangelical community what it is like to engage in respectful and meaningful exploration of a viewpoint with which we disagree on key points

The Story of the Cosmos Daniel Ray, Paul Gould, 2019-07-16 Unraveling the Mysteries of the Universe What do you see when you gaze at the night sky Do you contemplate the stars as the random result of an evolutionary process Or do you marvel over them as a testament of the Creator's glory Modern science has popularized a view of the cosmos that suggests there is no need for God and denies any evidence of His existence But The Story of the Cosmos provides a different and fascinating perspective It points to a God who makes Himself known in the wonder and beauty of His creation This compilation from respected scholars and experts spans topics from The Mathematical Creation and the Image of God to The Glorious Dance of Binary Stars and God's Invisible Attributes Black Holes Contributors include Dr William Lane Craig Dr Guillermo Gonzalez Dr Melissa Cain Travis and Dr Michael Ward Come take a deeper look at the universe and explore the traces of God's glory in the latest discoveries of astronomy science literature and art

Philosophy of Religion William Lane Craig, 2002 Philosophy of

Religion is a combined anthology and guide intended for use as a textbook in courses on Philosophy of Religion It aims to bring to the student the very best of cutting edge work on important topics in the field Presenting a sympathetic view of the topics it treats Philosophy of Religion provides an ideal resource for studying the central questions raised by religious belief

Proceedings of the 7th International Symposium Particles, Strings and Cosmology Kingman Cheung, John Francis Guion, Stephen Mrenna, 2000 The PASCOS International Symposium on Particles Strings and Cosmology series brings together the leading experts and most active young researchers in the closely related fields of elementary particle physics string theory and cosmology astrophysics These areas of research have become increasingly intertwined in recent years each having direct impact on the others In particular there has been a dramatic expansion of ideas from particle theory and string theory that have vast impact on cosmology especially our picture of the early universe and its evolution Correspondingly the proliferation of data regarding the early universe and its increasing precision has begun to strongly constrain the theoretical models Meanwhile observations of neutrino oscillations and cosmic ray excesses and limits on new physics from colliders and other particle experiments as well as the resulting restrictions on theoretical and phenomenological modeling are becoming ever stronger During PASCOS99 it became clear that the long awaited era of convergence of these fields is truly at hand The proceedings of PASCOS 99 reflect the accelerating overlap and convergence of the fields of elementary particles physics string theory and cosmology astrophysics Plenary reviews by leading figures in these fields provide perspectives on these interrelationships and up to the minute summaries of recent progress in the various areas Parallel talk summaries focus on many of the topics within each field of greatest current interest and activity Both the plenary and parallel writeups are designed to be descriptive in nature and avoid being overly technical As a result the volume can serve as a useful reference for students and professionals in all three fields Careful referencing allows further pursuit of a given topic Overall the proceedings are unique in that they not only bring together in a single volume comprehensive overview of the great progress being made in all three of these very exciting fields but also provide a snapshot of how particles strings and cosmology are increasingly impacting one another

[Introduction to General Relativity](#) Cosimo Bambi, 2018-06-18 Following the approach of Lev Landau and Evgenii Lifshitz this book introduces the theory of special and general relativity with the Lagrangian formalism and the principle of least action This method allows the complete theory to be constructed starting from a small number of assumptions and is the most natural approach in modern theoretical physics The book begins by reviewing Newtonian mechanics and Newtonian gravity with the Lagrangian formalism and the principle of least action and then moves to special and general relativity Most calculations are presented step by step as is done on the board in class The book covers recent advances in gravitational wave astronomy and provides a general overview of current lines of research in gravity It also includes numerous examples and problems in each chapter

Naturalism William Lane Craig, J.P. Moreland, 2002-01-04 Naturalism provides a rigorous analysis and critique of the major varieties of contemporary

philosophical naturalism The authors advocate the thesis that contemporary naturalism should be abandoned in light of the serious objections raised against it Contributors draw on a wide range of topics including epistemology the philosophy of science the philosophy of mind and agency and natural theology *Fourteenth Marcel Grossmann Meeting, The: On Recent Developments In Theoretical And Experimental General Relativity, Astrophysics, And Relativistic Field Theories - Proceedings Of The Mg14 Meeting On General Relativity (In 4 Parts)* Massimo Bianchi, Robert T Jantzen, Remo Ruffini, 2017-10-13 The four volumes of the proceedings of MG14 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 35 morning plenary talks over 6 days 6 evening popular talks and 100 parallel sessions on 84 topics over 4 afternoons Volume A contains plenary and review talks ranging 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 The remaining volumes include parallel sessions which 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 **The Nature of Nature** Bruce Gordon, William Dembski, 2014-04-29 The intellectual and cultural battles now raging over theism and atheism conservatism and secular progressivism dualism and monism realism and antirealism and transcendent reality versus material reality extend even into the scientific disciplines This stunning new volume captures this titanic clash of worldviews among those who have thought most deeply about the nature of science and of the universe itself Unmatched in its breadth and scope The Nature of Nature brings together some of the most influential scientists scholars and public intellectuals including three Nobel laureates across a wide spectrum of disciplines and schools of thought Here they grapple with a perennial question that has been made all the more pressing by recent advances in the natural sciences Is the fundamental explanatory principle of the universe life and self conscious awareness to be found in inanimate matter or immaterial mind The answers found in this book have profound implications for what it means to do science what it means to be human and what the future holds for all of us Thirteenth Marcel Grossmann Meeting, The: On Recent

Developments In Theoretical And Experimental General Relativity, Astrophysics And Relativistic Field Theories - Proceedings Of The Mg13 Meeting On General Relativity (In 3 Volumes) Remo Ruffini, Kjell Rosquist, Robert T Jantzen, 2015-01-26 The Marcel Grossmann Meetings seek to further the development of the foundations and applications of Einstein's general relativity by promoting theoretical understanding in the relevant fields of physics mathematics astronomy and astrophysics and to direct future technological observational and experimental efforts The meetings discuss recent developments in classical and quantum aspects of gravity and in cosmology and relativistic astrophysics with major emphasis on mathematical foundations and physical predictions having the main objective of gathering scientists from diverse backgrounds for deepening our understanding of spacetime structure and reviewing the current state of the art in the theory observations and experiments pertinent to relativistic gravitation The range of topics is broad going from the more abstract classical theory quantum gravity branes and strings to more concrete relativistic astrophysics observations and modeling The three volumes of the proceedings of MG13 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 33 morning plenary talks during 6 days and 75 parallel sessions over 4 afternoons Volume A contains plenary and review talks ranging from the mathematical foundations of classical and quantum gravitational theories including recent developments in string brane theories to precision tests of general relativity including progress towards the detection of gravitational waves and from supernova cosmology to relativistic astrophysics including such topics as gamma ray bursts black hole physics both in our galaxy and in active galactic nuclei in other galaxies and neutron star and pulsar astrophysics Volumes B and C include parallel sessions which touch on dark matter neutrinos X ray sources astrophysical black holes neutron stars 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 and cosmic rays and the history of general relativity

Particles, Strings And Cosmology (Pascos 99), Procs Of 7th Intl Symp Kingman Cheung, John F Gunion, Stephen Mrenna, 2000-08-30 The PASCOS International Symposium on Particles Strings and Cosmology series brings together the leading experts and most active young researchers in the closely related fields of elementary particle physics string theory and cosmology astrophysics These areas of research have become increasingly intertwined in recent years each having direct impact on the others In particular there has been a dramatic expansion of ideas from particle theory and string theory that have vast impact on cosmology especially our picture of the early universe

and its evolution Correspondingly the proliferation of data regarding the early universe and its increasing precision has begun to strongly constrain the theoretical models Meanwhile observations of neutrino oscillations and cosmic ray excesses and limits on new physics from colliders and other particle experiments as well as the resulting restrictions on theoretical and phenomenological modeling are becoming ever stronger During PASCOS99 it became clear that the long awaited era of convergence of these fields is truly at hand The proceedings of PASCOS 99 reflect the accelerating overlap and convergence of the fields of elementary particles physics string theory and cosmology astrophysics Plenary reviews by leading figures in these fields provide perspectives on these interrelationships and up to the minute summaries of recent progress in the various areas Parallel talk summaries focus on many of the topics within each field of greatest current interest and activity Both the plenary and parallel writeups are designed to be descriptive in nature and avoid being overly technical As a result the volume can serve as a useful reference for students and professionals in all three fields Careful referencing allows further pursuit of a given topic Overall the proceedings are unique in that they not only bring together in a single volume comprehensive overview of the great progress being made in all three of these very exciting fields but also provide a snapshot of how particles strings and cosmology are increasingly impacting one another

Sixteenth Marcel Grossmann Meeting, The: On Recent Developments In Theoretical And Experimental General Relativity, Astrophysics, And Relativistic Field Theories - Proceedings Of The Mg16 Meeting On General Relativity (In 4 Volumes) Remo Ruffini, Gregory

Vereshchagin, 2022-12-15 The proceedings of MG16 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 46 plenary presentations 3 public lectures 5 round tables and 81 parallel sessions arranged during the intense six day online meeting All talks were recorded and are available on the ICRANet YouTube channel at the following link www.icranet.org/video_mg16 These proceedings are a representative sample of the very many contributions made at the meeting They contain 383 papers among which 14 come from the plenary sessions The material represented in these proceedings cover the following topics accretion active galactic nuclei alternative theories of gravity black holes theory observations and experiments binaries boson stars cosmic microwave background cosmic strings dark energy and large scale structure dark matter education exact solutions early universe fundamental interactions and stellar evolution fast transients gravitational waves high energy physics history of relativity neutron stars precision tests quantum gravity strong fields and white dwarf all of them represented by a large number of contributions The online e proceedings are published in an open access format

Cosmological Crossroads Spiros Cotsakis, Eleftherios Papantonopoulos, 2008-01-11 History and Overview Is Nature Generic Evolution of Ideas in Modern Cosmology Mathematical Cosmology Constraints and Evolution in Cosmology Cosmological Singularities Exact Cosmological Solutions to Cosmological Dynamical Systems Astrophysical and Observational Cosmology The Quest for the Cosmological Parameters Modern Cosmological Observations Cosmological

Perturbations Dark Matter A Particle Theorist's Viewpoint Particle and String Cosmology An Introduction to Particle Physics
 Quantum Cosmology Inflationary Cosmology String Cosmology Brane Cosmology **Spacetime Singularities in Quantum Gravity** Eric Azarian Minassian, 2003 **Springer Handbook of Spacetime** Abhay Ashtekar, Vesselin Petkov, 2014-09-01
 The Springer Handbook of Spacetime is dedicated to the ground breaking paradigm shifts embodied in the two relativity theories and describes in detail the profound reshaping of physical sciences they ushered in. It includes in a single volume chapters on foundations on the underlying mathematics on physical and astrophysical implications experimental evidence and cosmological predictions as well as chapters on efforts to unify general relativity and quantum physics. The Handbook can be used as a desk reference by researchers in a wide variety of fields not only by specialists in relativity but also by researchers in related areas that either grew out of or are deeply influenced by the two relativity theories cosmology astronomy and astrophysics high energy physics quantum field theory mathematics and philosophy of science. It should also serve as a valuable resource for graduate students and young researchers entering these areas and for instructors who teach courses on these subjects. The Handbook is divided into six parts: Part A Introduction to Spacetime Structure; Part B Foundational Issues; Part C Spacetime Structure and Mathematics; Part D Confronting Relativity theories with observations; Part E General relativity and the universe; Part F Spacetime beyond Einstein. *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. **Introduction to Philosophy** George Thomas White Patrick, 1924 *Gravitation and Inertia* Ignazio Ciufolini, John Archibald Wheeler, 2018-06-26. Einstein's standard and battle tested geometric theory of gravity spacetime tells mass how to move and mass tells spacetime how to curve is expounded in this book by Ignazio Ciufolini and John Wheeler. They give special attention to the theory's observational checks and to two of its consequences: the predicted existence of gravitomagnetism and the origin of inertia. Local inertial frames in Einstein's general relativity: inertia here arises from mass there. The authors explain the modern understanding of the link between gravitation and inertia in Einstein's theory from the origin of inertia in some cosmological models of the universe to the interpretation of the initial value formulation of Einstein's standard geometrodynamics and from the devices and the methods used to determine the local

inertial frames of reference to the experiments used to detect and measure the dragging of inertial frames of reference In this book Ciufolini and Wheeler emphasize present past and proposed tests of gravitational interaction metric theories and general relativity They describe the numerous confirmations of the foundations of geometrodynamics and some proposed experiments including space missions to test some of its fundamental predictions in particular gravitomagnetic field or dragging of inertial frames and gravitational waves

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