

INSTITUTE OF PHYSICS
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GRAVITATION AND GAUGE SYMMETRIES

MILUTIN BLAGOJEVIĆ

Gravitation And Gauge Symmetries

Milutin Blagojević



Gravitation And Gauge Symmetries:

Gravitation and Gauge Symmetries M Blagojevic, 2001-10-25 In the course of the development of electromagnetic weak and strong interactions the concept of internal gauge invariance grew up and established itself as an unavoidable dynamical principle in particle physics It is less known that the principle of equivalence and the basic dynamical properties of the gravitational interaction can also be expressed as a spacetime gauge symmetry

Gravitation and Gauge Symmetries Milutin Blagojević, 2002 In the course of the development of electromagnetic weak and strong interactions the concept of internal gauge invariance grew up and established itself as an unavoidable dynamical principle in particle physics It is less known that the principle of equivalence and the basic dynamical properties of the gravitational interaction can also be expressed as a spacetime gauge symmetry

Gravitation and Gauge Symmetries sheds light on the connection between the intrinsic structure of gravity and the principle of gauge invariance which may lead to a consistent unified field theory The first part of the book gives a systematic account of the structure of gravity as a theory based on spacetime gauge symmetries Some basic properties of space time and gravity are reviewed in the first introductory chapter The next chapter deals with elements of global Poincare and conformal symmetries which are necessary for the exposition of their localizations the structure of the corresponding gauge theories of gravity is explored in chapters 3 and 4 Then in chapters 5 and 6 we present the basic features of the constrained Hamiltonian of Poincare gauge theory discuss the relation between gauge symmetries and conservation laws and introduce the concept of gravitational energy and other conserved quantities The second part of the book explores the most promising attempts to build a unified field theory containing gravity on the basis of the gauge principle The author presents the possibility to constrict the theory of gravity as a nonlinear field theory in flat spacetime The final chapters yield an exposition of the ideas of supersymmetry and supergravity Kaluza Klein theory and string theory *Gravitation and Gauge Symmetries* will be of interest to postgraduate students and researchers in gravitation high energy physics and mathematical physics

Gravitation, Gauge Theories and the Early Universe B.R. Iyer, N. Mukunda, C.V. Vishveshwara, 2012-12-06 This book evolved out of some one hundred lectures given by twenty experts at a special instructional conference sponsored by the University Grants Commission India It is pedagogical in style and self contained in several interrelated areas of physics which have become extremely important in present day theoretical research The articles begin with an introduction to general relativity and cosmology as well as particle physics and quantum field theory This is followed by reviews of the standard gauge models of high energy physics renormalization group and grand unified theories The concluding parts of the book comprise discussions in current research topics such as problems of the early universe quantum cosmology and the new directions towards a unification of gravitation with other forces In addition special concise treatments of mathematical topics of direct relevance are also included The content of the book was carefully worked out for the mutual education of students and research workers in general relativity and particle physics This ambitious programme consequently necessitated the

involvement of a number of different authors However care has been taken to ensure that the material meshes into a unified cogent and readable book We hope that the book will serve to initiate and guide a student in these different areas of investigation starting from first principles and leading to the exciting current research problems of an interdisciplinary nature in the context of the origin and structure of the universe

Gravitation and Spacetime Hans C. Ohanian, Remo Ruffini, 2013-04-08 This text provides a quantitative introduction to general relativity for advanced undergraduate and graduate students

Modified and Quantum Gravity Christian Pfeifer, Claus Lämmerzahl, 2023-09-30 This book discusses theoretical predictions and their comparison with experiments of extended and modified classical and quantum theories of gravity The goal is to provide a readable access and broad overview over different approaches to the topic to graduate and PhD students as well as to young researchers The book presents both theoretical and experimental insights and is structured in three parts The first addresses the theoretical models beyond special and general relativity such as string theory Poincare gauge theory and teleparallelism as well as Finsler gravity In turn the second part is focused on the observational effects that these models generate accounting for tests and comparisons which can be made on all possible scales from the universe as a whole via binary systems stars black holes satellite experiments down to laboratory experiments at micrometer and smaller scales The last part of this book is dedicated to quantum systems and gravity showing tests of classical gravity with quantum systems and coupling of quantum matter and gravity

One Hundred Years Of General Relativity: From Genesis And Empirical Foundations To Gravitational Waves, Cosmology And Quantum Gravity - Volume 1 Wei-tou Ni, 2017-05-26 The aim of this two volume title is to give a comprehensive review of one hundred years of development of general relativity and its scientific influences This unique title provides a broad introduction and review to the fascinating and profound subject of general relativity its historical development its important theoretical consequences gravitational wave detection and applications to astrophysics and cosmology The series focuses on five aspects of the theory The first three topics are covered in Volume 1 and the remaining two are covered in Volume 2 While this is a two volume title it is designed so that each volume can be a standalone reference volume for the related topic

[Trends in General Relativity and Quantum Cosmology](#) Charles V. Benton, 2006 Cosmology deals with the nature of the universe It can be broadly divided into three great ages The first began in the 6th century BC with the Pythagorean concept of a spherical Earth that is part of a universe in which the motions of the planets are governed by the harmonious relations of natural laws The second began in the 16th century with the Copernican revolution This in turn led into Newton's infinite universe The third began in the early 20th century with Albert Einstein's theory of general relativity and developed into the expanding universe we know today Einstein's general theory of relativity extended the new space and time concepts of the special theory of relativity from the domain of electric and magnetic phenomena to all of physics and particularly to the theory of gravitation By building on Einstein's previous work on special relativity general relativity sought to deal with accelerating frames of reference This in turn led to the

principle of equivalence By dealing with accelerating frames of reference general relativity provides astronomers with the best theory to predict the effects of gravity This book examines in detail new and important work in this field

Symmetries in Fundamental Physics Kurt Sundermeyer, 2014-07-23 Over the course of the last century it has become clear that both elementary particle physics and relativity theories are based on the notion of symmetries These symmetries become manifest in that the laws of nature are invariant under spacetime transformations and or gauge transformations The consequences of these symmetries were analyzed as early as in 1918 by Emmy Noether on the level of action functionals Her work did not receive due recognition for nearly half a century but can today be understood as a recurring theme in classical mechanics electrodynamics and special relativity Yang Mills type quantum field theories and in general relativity As a matter of fact as shown in this monograph many aspects of physics can be derived solely from symmetry considerations This substantiates the statement of E P Wigner if we knew all the laws of nature or the ultimate Law of nature the invariance properties of these laws would not furnish us new information Thanks to Wigner we now also understand the implications of quantum physics and symmetry considerations Poincare invariance dictates both the characteristic properties of particles mass spin and the wave equations of spin 0 1 2 1 objects Further the work of C N Yang and R Mills reveals the consequences of internal symmetries as exemplified in the symmetry group of elementary particle physics Given this pivotal role of symmetries it is thus not surprising that current research in fundamental physics is to a great degree motivated and inspired by considerations of symmetry The treatment of symmetries in this monograph ranges from classical physics to now well established theories of fundamental interactions to the latest research on unified theories and quantum gravity **Broken**

Symmetry in Curved Spacetime and Gravity Charles D. Lane, 2020-11-13 This book contains several recent articles written about broken spacetime symmetry The context is curved spacetime as used in General Relativity and the broken symmetry most discussed is Local Lorentz Symmetry While there is currently no experimental evidence for broken Lorentz symmetry in nature it is an object of great study from theoretical phenomenological and experimental perspectives All three appear in this volume There are three review articles in this volume Fabian Kislak summarizes astrophysical probes of Lorentz violation especially those using polarized light Michael Seifert discusses a particular limit of the Standard Model Extension that is useful for relating theoretical and experimental ideas and Marco Schreck describes circumstances under which gravitational Cerenkov radiation could arise from Lorentz violation The other three articles focus more on original research Charles Lane and Quentin Bailey relate a particular theory of noncommutative geometry to the curved spacetime Standard Model Extension Yuri Bonder and Christobal Corral consider the existence of spacetime symmetries in models with explicit Lorentz violation and Pawel Gusin et al study a spacetime transformation that relates the inside and outside of a nonrotating black hole Space-time Symmetry and Quantum Yang-Mills Gravity Jong-Ping Hsu, Leon Hsu, 2013

Yang-O CoMills gravity is a new theory consistent with experiments that brings gravity back to the arena of gauge field theory

and quantum mechanics in flat space time It provides solutions to long standing difficulties in physics such as the incompatibility between Einstein's principle of general coordinate invariance and modern schemes for a quantum mechanical description of nature and Noether's theorem which showed that the principle of general coordinate invariance in general relativity leads to the failure of the law of conservation of energy Yang-Mills gravity in flat space time appears to be more physically coherent than conventional gravity in curved space time The problems of quantization of the gravitational field the operational meaning of space time coordinates and momenta and the conservation of energy momentum are all resolved in Yang-Mills gravity The aim of this book is to provide a treatment of quantum Yang-Mills gravity with an emphasis on the ideas and evidence that the gravitational field is the manifestation of space time translational symmetry in flat space time and that there exists a fundamental space time symmetry framework that can encompass all of physics including gravity for all inertial and non inertial frames of reference

Geometry of the Fundamental Interactions M. D. Maia, 2011-06-14 The Yang Mills theory of gauge interactions is a prime example of interdisciplinary mathematics and advanced physics Its historical development is a fascinating window into the ongoing struggle of mankind to understand nature The discovery of gauge fields and their properties is the most formidable landmark of modern physics The expression of the gauge field strength as the curvature associated to a given connection places quantum field theory in the same geometrical footing as the gravitational field of general relativity which is naturally written in geometrical terms The understanding of such geometrical property may help one day to write a unified field theory starting from symmetry principles Of course there are remarkable differences between the standard gauge fields and the gravitational field which must be understood by mathematicians and physicists before attempting such unification In particular it is important to understand why gravitation is not a standard gauge field This book presents an account of the geometrical properties of gauge field theory while trying to keep the equilibrium between mathematics and physics At the end we will introduce a similar approach to the gravitational field

Introductory Lectures on Higher-Spin Theories Stefan Fredenhagen, 2024-09-15 The book offers a pedagogical introduction to higher spin gauge theories These theories build upon fundamental gauge theories that are crucial for understanding core interactions Electromagnetism and nuclear forces are associated with gauge fields of spin 1 while gravity can be conceptualized as a gauge theory of spin 2 This prompts the intriguing inquiry do higher spin gauge theories exist Such theories would extend gravity incorporating massless gauge fields of spins higher than two They appear to bear connections to string theory and offer a captivating framework for exploring gravity and aspects of quantum gravity The book initiates with a primer offering a comprehensive discussion on higher spins delving into the challenges of establishing coherent interactions It then explores methodologies to surmount these challenges within three dimensional space time Furthermore it investigates the emergence of asymptotic symmetry algebras establishing links to a holographic dual conformal theory The final chapter introduces Vasiliev's approach to higher spin

gauge theory in four dimensions Designed for advanced students and young researchers in theoretical physics and mathematical physics the book aims to elucidate fundamental ideas concepts and tools underpinning higher spin gauge theories The inclusion of numerous exercises complements and illustrates the content preparing readers for engagement with the subject s original literature and ongoing developments To fully engage with the book s arguments a prerequisite understanding of field theories and conventional gauge theories including gravity is assumed *Noether's Theorems* Gennadi Sardanashvily,2016-03-18 The book provides a detailed exposition of the calculus of variations on fibre bundles and graded manifolds It presents applications in such area s as non relativistic mechanics gauge theory gravitation theory and topological field theory with emphasis on energy and energy momentum conservation laws Within this general context the first and second Noether theorems are treated in the very general setting of reducible degenerate graded Lagrangian theory

Gravity, Gauge Theories and Quantum Cosmology J.V. Narlikar,T. Padmanabhan,2012-12-06 For several decades since its inception Einstein s general theory of relativity stood somewhat aloof from the rest of physics Paradoxically the attributes which normally boost a physical theory namely its perfection as a theoreti cal framework and the extraordinary intellectual achievement underlying i prevented the general theory from being assimilated in the mainstream of physics It was as if theoreticians hesitated to tamper with something that is manifestly so beautiful Happily two developments in the 1970s have narrowed the gap In 1974 Stephen Hawking arrived at the remarkable result that black holes radiate after all And in the second half of the decade particle physicists discovered that the only scenario for applying their grand unified theories was offered by the very early phase in the history of the Big Bang universe In both cases it was necessary to discuss the ideas of quantum field theory in the background of curved spacetime that is basic to general relativity This is however only half the total story If gravity is to be brought into the general fold of theoretical physics we have to know how to quantize it To date this has proved a formidable task although most physicists would agree that as in the case of grand unified theories quantum gravity will have applications to cosmology in the very early stages of the Big Bang universe In fact the present picture of the Big Bang universe necessarily forces us to think of quantum cosmology Relativity and Gravitation Jiří Bičák,Tomáš Ledvinka,2014-06-06 In early April 1911 Albert Einstein arrived in Prague to become full professor of theoretical physics at the German part of Charles University It was there for the first time that he concentrated primarily on the problem of gravitation Before he left Prague in July 1912 he had submitted the paper Relativit t und Gravitation Erwiderung auf eine Bemerkung von M Abraham in which he remarkably anticipated what a future theory of gravity should look like At the occasion of the Einstein in Prague centenary an international meeting was organized under a title inspired by Einstein s last paper from the Prague period Relativity and Gravitation 100 Years after Einstein in Prague The main topics of the conference included classical relativity numerical relativity relativistic astrophysics and cosmology quantum gravity experimental aspects of gravitation and conceptual and historical issues The conference attracted over 200

scientists from 31 countries among them a number of leading experts in the field of general relativity and its applications This volume includes abstracts of the plenary talks and full texts of contributed talks and articles based on the posters presented at the conference These describe primarily original results of the authors Full texts of the plenary talks are included in the volume *General Relativity Cosmology and Astrophysics Perspectives 100 Years after Einstein* in Prague eds J Bi k and T Ledvinka published also by Springer Verlag *Relativity, Gravitation, Cosmology* Valeri V. Dvoeglazov, Augusto A. Espinoza Garrido, 2004 This volume consists of 14 papers The editors are well known experts in the problems of modern physics R Yamaleev J Kocinski and M Wierzbicki R K hne J Garecki S Tiwari R Amoroso and J P Vigier A Camacho S Ghosh L Horwitz and O Oron G j Ni I Eganova R Kiehn R Cahill are among the authors New developments in the well established theories Kaluza Klein 5 dimensional theories torsion the Weyl unified theory quantum foam space time non commutativity negative mass paradox in the neutrino physics etc

Handbook of Quantum Gravity Cosimo Bambi, Leonardo Modesto, Ilya Shapiro, 2024-12-03 The search for a theory of quantum gravity is one of the most important and fascinating problems in modern theoretical physics While we do not have yet a complete theory of quantum gravity significant advancements have been done in the past decades In this handbook every section is dedicated to a specific approach towards a theory of quantum gravity and is edited by the leading experts in the field This book represents both a valuable resource for graduate students and an important reference for researchers in quantum gravity

Geometrodynamics of Gauge Fields Eckehard W. Mielke, 2017-01-22 This monograph aims to provide a unified geometrical foundation of gauge theories of elementary particle physics The underlying geometrical structure is unfolded in a coordinate free manner via the modern mathematical notions of fibre bundles and exterior forms Topics such as the dynamics of Yang Mills theories instanton solutions and topological invariants are included By transferring these concepts to local space time symmetries generalizations of Einstein s theory of gravity arise in a Riemann Cartan space with curvature and torsion It provides the framework in which the broken Poincar gauge theory the Rainich geometrization of the Einstein Maxwell system and higher dimensional non abelian Kaluza Klein theories are developed Since the discovery of the Higgs boson concepts of spontaneous symmetry breaking in gravity have come again into focus and in this revised edition these will be exposed in geometric terms Quantizing gravity remains an open issue formulating it as a de Sitter type gauge theory in the spirit of Yang Mills some new progress in its topological form is presented After symmetry breaking Einstein s standard general relativity with cosmological constant emerges as a classical background The geometrical structure of BRST quantization with non propagating topological ghosts is developed in some detail

Lectures on the Infrared Structure of Gravity and Gauge Theory Andrew Strominger, 2018-03-06 A short graduate level synthesis of recent developments in theoretical physics from a pioneer in the field *Lectures on the Infrared Structure of Gravity and Gauge Theory* presents an accessible graduate level synthesis of a frontier research area in theoretical physics Based on a popular Harvard University course taught by the

author this book gives a concise introduction to recent discoveries concerning the structure of gravity and gauge theory at very long distances These discoveries unite three disparate but well developed subjects in physics The first subject is the soft theorems which were found by particle physicists in the 1950s to control the behavior of low energy photons and are essential for all collider predictions The second subject is asymptotic symmetries found by general relativists in the 1960s to provide a surprising infinite number of exact relations between distinct physical phenomena The third subject is the memory effect the measurement of which is sought in upcoming gravitational wave observations An exploration of the physical and mathematical equivalence of these three subjects has provided a powerful new perspective on old results and led to a plethora of new results involving symmetries of QED gluon scattering amplitudes flat space holography in quantum gravity black hole information and beyond Uniquely connective and cutting edge Lectures on the Infrared Structure of Gravity and Gauge Theory takes students and scholars to the forefront of new developments in the discipline Materials are presented in a lecture notes style with problem sets included Concise and accessible pedagogical approach Topics include soft theorems the memory effect asymptotic symmetries with applications to QED Yang Mills theory quantum gravity and black holes

Clifford (Geometric) Algebras William E. Baylis, 2012-12-06 This volume is an outgrowth of the 1995 Summer School on Theoretical Physics of the Canadian Association of Physicists CAP held in Banff Alberta in the Canadian Rockies from July 30 to August 12 1995 The chapters based on lectures given at the School are designed to be tutorial in nature and many include exercises to assist the learning process Most lecturers gave three or four fifty minute lectures aimed at relative novices in the field More emphasis is therefore placed on pedagogy and establishing comprehension than on erudition and superior scholarship Of course new and exciting results are presented in applications of Clifford algebras but in a coherent and user friendly way to the nonspecialist The subject area of the volume is Clifford algebra and its applications Through the geometric language of the Clifford algebra approach many concepts in physics are clarified united and extended in new and sometimes surprising directions In particular the approach eliminates the formal gaps that traditionally separate classical quantum and relativistic physics It thereby makes the study of physics more efficient and the research more penetrating and it suggests resolutions to a major physics problem of the twentieth century namely how to unite quantum theory and gravity The term geometric algebra was used by Clifford himself and David Hestenes has suggested its use in order to emphasize its wide applicability and because the developments by Clifford were themselves based heavily on previous work by Grassmann Hamilton Rodrigues Gauss and others

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