Editorial

Noncommutative geometry in physics

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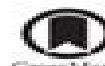[4] Uniwersytet Jagielloński w Krakowie Wydział Fizyki Astronomii i Informatyki Stosowanej, Lojasiewicza 11, Krakow 30-348, Poland

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Noncommutative geometry is a broad mathematical paradigm derived from various branches of mathematics (including operator algebras, differential geometry, index theory, and others) and physics (including quantum mechanics and quantum field theory). As a result, it pervades various research directions in both disciplines. Through topical reviews and research papers, the goal of this issue is to present an up-to-date account of the many aspects of the emergence of noncommutativity in theoretical and mathematical physics.

It should help the scientific community recognize how active the field is due to the wide range of research topics it addresses: quantum field theory, renormalization, string theory, topological states of matter, condensed matter, exactly solvable models in quantum statistical mechanics, elementary particle physics (Standard Model and grand unified theories), gravity, quantum cosmology, and quantum gravity phenomenology.

Moreover, we hope that this issue will have an impact on the larger physics community and help it overcome the frequent language difficulty associated with noncommutative geometry, which is due to its cross-disciplinary nature and the application of advanced mathematics from various research fields. The aim is to present physics as described in noncommutative geometry and to motivate noncommutative geometries in light of their relevance and potential applications in physics without sacrificing mathematical rigor. As a result, this volume helps to bridge the gap between the mathematics and physics communities who are interested in noncommutative geometry physics.

This issue contains six topical reviews and sixteen peer-reviewed research papers, and it was originally accompanied by a series of seminars held monthly in 2021.

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Noncommutative Geometry And Physics

Florian Scheck,Wend Werner,Harald Upmeier

Noncommutative Geometry And Physics:

   Noncommutative Geometry and Particle Physics Walter D. van Suijlekom,2014-07-21 This book provides an introduction to noncommutative geometry and presents a number of its recent applications to particle physics It is intended for graduate students in mathematics theoretical physics who are new to the field of noncommutative geometry as well as for researchers in mathematics theoretical physics with an interest in the physical applications of noncommutative geometry In the first part we introduce the main concepts and techniques by studying finite noncommutative spaces providing a light approach to noncommutative geometry We then proceed with the general framework by defining and analyzing noncommutative spin manifolds and deriving some main results on them such as the local index formula In the second part we show how noncommutative spin manifolds naturally give rise to gauge theories applying this principle to specific examples We subsequently geometrically derive abelian and non abelian Yang Mills gauge theories and eventually the full Standard Model of particle physics and conclude by explaining how noncommutative geometry might indicate how to proceed beyond the Standard Model   *Noncommutative Geometry and Physics* Alan L. Carey,2011 This collection of expository articles grew out of the workshop Number Theory and Physics held in March 2009 at The Erwin Schrodinger International Institute for Mathematical Physics Vienna The common theme of the articles is the influence of ideas from noncommutative geometry NCG on subjects ranging from number theory to Lie algebras index theory and mathematical physics Matilde Marcolli s article gives a survey of relevant aspects of NCG in number theory building on an introduction to motives for beginners by Jorge Plazas and Sujatha Ramdorai A mildly unconventional view of index theory from the viewpoint of NCG is described in the article by Alan Carey John Phillips and Adam Rennie As developed by Alain Connes and Dirk Kreimer NCG also provides insight into novel algebraic structures underlying many analytic aspects of quantum field theory Dominique Manchon s article on pre Lie algebras fits into this developing research area This interplay of algebraic and analytic techniques also appears in the articles by Christoph Bergbauer who introduces renormalization theory and Feynman diagram methods and Sylvie Paycha who focuses on relations between renormalization and zeta function techniques   **Noncommutative Geometry and Physics** ,2005   **Noncommutative Geometry and Physics 3** Giuseppe Dito,Motoko Kotani,Yoshiaki Maeda,2013 Noncommutative differential geometry has many actual and potential applications to several domains in physics ranging from solid state to quantization of gravity The strategy is to formulate usual differential geometry in a somewhat unusual manner using in particular operator algebras and related concepts so as to be able to plug in noncommutativity in a natural way Algebraic tools such as K theory and cyclic cohomology and homology play an important role in this field

   Noncommutative Geometry and Number Theory Caterina Consani,Matilde Marcolli,2007-12-18 In recent years number theory and arithmetic geometry have been enriched by new techniques from noncommutative geometry operator algebras dynamical systems and K Theory This volume collects and presents up to date research topics in arithmetic and

noncommutative geometry and ideas from physics that point to possible new connections between the fields of number theory algebraic geometry and noncommutative geometry The articles collected in this volume present new noncommutative geometry perspectives on classical topics of number theory and arithmetic such as modular forms class field theory the theory of reductive p adic groups Shimura varieties the local L factors of arithmetic varieties They also show how arithmetic appears naturally in noncommutative geometry and in physics in the residues of Feynman graphs in the properties of noncommutative tori and in the quantum Hall effect *Noncommutative Geometry* Alain Connes,1994-11-22 This English version of the path breaking French book on this subject gives the definitive treatment of the revolutionary approach to measure theory geometry and mathematical physics developed by Alain Connes Profusely illustrated and invitingly written this book is ideal for anyone who wants to know what noncommutative geometry is what it can do or how it can be used in various areas of mathematics quantization and elementary particles and fields First full treatment of the subject and its applications Written by the pioneer of this field Broad applications in mathematics Of interest across most fields Ideal as an introduction and survey Examples treated include the space of Penrose tilings the space of leaves of a foliation the space of irreducible unitary representations of a discrete group the phase space in quantum mechanics the Brillouin zone in the quantum Hall effect A model of space time Noncommutative Geometry And Physics 4 - Workshop On Strings, Membranes And Topological Field Theory Yoshiaki Maeda,Hitoshi Moriyoshi,Motoko Kotani,Satoshi Watamura,2017-03-16 This book is a collection of the lectures and talks presented in the Tohoku Forum for Creativity in the thematic year 2015 Fundamental Problems in Quantum Physics Strings Black Holes and Quantum Information and related events in the period 2014 2016 This volume especially contains an overview of recent developments in the theory of strings and membranes as well as topological field theory Noncommutative Geometry and the Standard Model of Elementary Particle Physics Florian Scheck,Wend Werner,Harald Upmeier,2002-11-26 The outcome of a close collaboration between mathematicians and mathematical physicists these Lecture Notes present the foundations of A Connes noncommutative geometry as well as its applications in particular to the field of theoretical particle physics The coherent and systematic approach makes this book useful for experienced researchers and postgraduate students alike **Noncommutative Geometry and Physics, 3** Giuseppe Dito,Yoshiaki Maeda,Motoko Kotani,2013 Noncommutative differential geometry is a novel approach to geometry aimed in part at applications in physics It was founded in the early eighties by the 1982 Fields Medalist Alain Connes on the basis of his fundamental works in operator algebras It is now a very active branch of mathematics with actual and potential applications to a variety of domains in physics ranging from solid state to quantization of gravity The strategy is to formulate usual differential geometry in a somewhat unusual manner using in particular operator algebras and related concepts so as to be able to plug in noncommutativity in a natural way Algebraic tools such as K theory and cyclic cohomology and homology play an important role in this field It is an important topic both for mathematics and physics *Noncommutative Geometry*

and the Standard Model of Elementary Particle Physics Florian Scheck,Wend Werner,Harald Upmeier,2014-03-12

Noncommutative Geometry and Particle Physics Walter van Suijlekom,2014-07-27 This book provides an introduction to noncommutative geometry and presents a number of its recent applications to particle physics It is intended for graduate students in mathematics theoretical physics who are new to the field of noncommutative geometry as well as for researchers in mathematics theoretical physics with an interest in the physical applications of noncommutative geometry In the first part we introduce the main concepts and techniques by studying finite noncommutative spaces providing a light approach to noncommutative geometry We then proceed with the general framework by defining and analyzing noncommutative spin manifolds and deriving some main results on them such as the local index formula In the second part we show how noncommutative spin manifolds naturally give rise to gauge theories applying this principle to specific examples We subsequently geometrically derive abelian and non abelian Yang Mills gauge theories and eventually the full Standard Model of particle physics and conclude by explaining how noncommutative geometry might indicate how to proceed beyond the Standard Model **Noncommutative Spacetimes** Paolo Aschieri,2009-07-14 There are many approaches to noncommutative geometry and to its use in physics This volume addresses the subject by combining the deformation quantization approach based on the notion of star product and the deformed quantum symmetries methods based on the theory of quantum groups The aim of this work is to give an introduction to this topic and to prepare the reader to enter the research field quickly The order of the chapters is physics first the mathematics follows from the physical motivations e g gauge field theories in order to strengthen the physical intuition The new mathematical tools in turn are used to explore further physical insights A last chapter has been added to briefly trace Julius Wess 1934 2007 seminal work in the field

Quantum Field Theory and Noncommutative Geometry Ursula Carow-Watamura,Yoshiaki Maeda,2005-02-21 This volume reflects the growing collaboration between mathematicians and theoretical physicists to treat the foundations of quantum field theory using the mathematical tools of q deformed algebras and noncommutative differential geometry A particular challenge is posed by gravity which probably necessitates extension of these methods to geometries with minimum length and therefore quantization of space This volume builds on the lectures and talks that have been given at a recent meeting on Quantum Field Theory and Noncommutative Geometry A considerable effort has been invested in making the contributions accessible to a wider community of readers so this volume will not only benefit researchers in the field but also postgraduate students and scientists from related areas wishing to become better acquainted with this field Noncommutative Geometry and Physics 2005 ,2007 This book provides a comprehensive overview of the authors pioneering contributions to nonlinear set valued analysis by topological methods The coverage includes fixed point theory degree theory the KKM principle variational inequality theory the Nash equilibrium point in mathematical economics the Pareto optimum in optimization and applications to best approximation theory partial equations and boundary value problems Self contained

and unified in presentation the book considers the existence of equilibrium points of abstract economics in topological vector spaces from the viewpoint of Ky Fan minimax inequalities It also provides the latest developments in KKM theory and degree theory for nonlinear set valued mappings **Quantization, Geometry and Noncommutative Structures in Mathematics and Physics** Alexander Cardona,Pedro Morales,Hernán Ocampo,Sylvie Paycha,Andrés F. Reyes Lega,2017-10-26 This monograph presents various ongoing approaches to the vast topic of quantization which is the process of forming a quantum mechanical system starting from a classical one and discusses their numerous fruitful interactions with mathematics The opening chapter introduces the various forms of quantization and their interactions with each other and with mathematics A first approach to quantization called deformation quantization consists of viewing the Planck constant as a small parameter This approach provides a deformation of the structure of the algebra of classical observables rather than a radical change in the nature of the observables When symmetries come into play deformation quantization needs to be merged with group actions which is presented in chapter 2 by Simone Gutt The noncommutativity arising from quantization is the main concern of noncommutative geometry Allowing for the presence of symmetries requires working with principal fiber bundles in a non commutative setup where Hopf algebras appear naturally This is the topic of chapter 3 by Christian Kassel Nichols algebras a special type of Hopf algebras are the subject of chapter 4 by Nicol s Andruskiewitsch The purely algebraic approaches given in the previous chapters do not take the geometry of space time into account For this purpose a special treatment using a more geometric point of view is required An approach to field quantization on curved space time with applications to cosmology is presented in chapter 5 in an account of the lectures of Abhay Ashtekar that brings a complementary point of view to non commutativity An alternative quantization procedure is known under the name of string theory In chapter 6 its supersymmetric version is presented Superstrings have drawn the attention of many mathematicians due to its various fruitful interactions with algebraic geometry some of which are described here The remaining chapters discuss further topics as the Batalin Vilkovisky formalism and direct products of spectral triples This volume addresses both physicists and mathematicians and serves as an introduction to ongoing research in very active areas of mathematics and physics at the border line between geometry topology algebra and quantum field theory *An Introduction to Noncommutative Geometry* Joseph C. Várilly,2006 Noncommutative geometry inspired by quantum physics describes singular spaces by their noncommutative coordinate algebras and metric structures by Dirac like operators Such metric geometries are described mathematically by Connes theory of spectral triples These lectures delivered at an EMS Summer School on noncommutative geometry and its applications provide an overview of spectral triples based on examples This introduction is aimed at graduate students of both mathematics and theoretical physics It deals with Dirac operators on spin manifolds noncommutative tori Moyal quantization and tangent groupoids action functionals and isospectral deformations The structural framework is the concept of a noncommutative spin geometry the conditions on spectral triples which

determine this concept are developed in detail The emphasis throughout is on gaining understanding by computing the details of specific examples The book provides a middle ground between a comprehensive text and a narrowly focused research monograph It is intended for self study enabling the reader to gain access to the essentials of noncommutative geometry New features since the original course are an expanded bibliography and a survey of more recent examples and applications of spectral triples *Noncommutative Structures in Mathematics and Physics* Steven Duplij,Julius Wess,2001-05-31 A presentation of outstanding achievements and ideas of both eastern and western scientists both mathematicians and physicists Their presentations of recent work on quantum field theory supergravity M theory black holes and quantum gravity together with research into noncommutative geometry Hopf algebras representation theory categories and quantum groups take the reader to the forefront of the latest developments Other topics covered include supergravity and branes supersymmetric quantum mechanics and superparticles super black holes superalgebra representations and SUSY GUT phenomenology Essential reading for workers in the modern methods of theoretical and mathematical physics

Noncommutative Differential Geometry and Its Applications to Physics Yoshiaki Maeda,Hitoshi Moriyoshi,Hideki Omori,Daniel Sternheimer,Tatsuya Tate,Satoshi Watamura,2001-03-31 Noncommutative differential geometry is a new approach to classical geometry It was originally used by Fields Medalist A Connes in the theory of foliations where it led to striking extensions of Atiyah Singer index theory It also may be applicable to hitherto unsolved geometric phenomena and physical experiments However noncommutative differential geometry was not well understood even among mathematicians Therefore an international symposium on commutative differential geometry and its applications to physics was held in Japan in July 1999 Topics covered included deformation problems Poisson groupoids operad theory quantization problems and D branes The meeting was attended by both mathematicians and physicists which resulted in interesting discussions This volume contains the refereed proceedings of this symposium Providing a state of the art overview of research in these topics this book is suitable as a source book for a seminar in noncommutative geometry and physics **Supersymmetry and Noncommutative Geometry** Wim Beenakker,Thijs van den Broek,Walter D. Suijlekom,2015-10-22 In this work the question whether noncommutative geometry allows for supersymmetric theories is addressed Noncommutative geometry has seen remarkable applications in high energy physics viz the geometrical interpretation of the Standard Model however such a question has not been answered in a conclusive way so far The book starts with a systematic analysis of the possibilities for so called almost commutative geometries on a 4 dimensional flat background to exhibit not only a particle content that is eligible for supersymmetry but also have a supersymmetric action An approach is proposed in which the basic building blocks of potentially supersymmetric theories and the demands for their action to be supersymmetric are identified It is then described how a novel kind of soft supersymmetry breaking Lagrangian arises naturally from the spectral action Finally the above formalism is applied to explore the existence of a noncommutative version of the minimal supersymmetric Standard

Model This book is intended for mathematical theoretical physicists with an interest in the applications of noncommutative geometry to supersymmetric field theories **Spectral Action in Noncommutative Geometry** Michał Eckstein,Bruno Iochum,2018-12-18 What is spectral action how to compute it and what are the known examples This book offers a guided tour through the mathematical habitat of noncommutative geometry la Connes deliberately unveiling the answers to these questions After a brief preface flashing the panorama of the spectral approach a concise primer on spectral triples is given Chapter 2 is designed to serve as a toolkit for computations The third chapter offers an in depth view into the subtle links between the asymptotic expansions of traces of heat operators and meromorphic extensions of the associated spectral zeta functions Chapter 4 studies the behaviour of the spectral action under fluctuations by gauge potentials A subjective list of open problems in the field is spelled out in the fifth Chapter The book concludes with an appendix including some auxiliary tools from geometry and analysis along with examples of spectral geometries The book serves both as a compendium for researchers in the domain of noncommutative geometry and an invitation to mathematical physicists looking for new concepts

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