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Series

Volume 36

Arithmetic  
Noncommutative  
Geometry

Matilde Marcolli



American Mathematical Society

# Arithmetic Noncommutative Geometry

**Alain Connes**



## **Arithmetic Noncommutative Geometry:**

*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

**Arithmetic Noncommutative Geometry** Matilde Marcolli, 2005 Arithmetic Noncommutative Geometry uses ideas and tools from noncommutative geometry to address questions in a new way and to reinterpret results and constructions from number theory and arithmetic algebraic geometry This general philosophy is applied to the geometry and arithmetic of modular curves and to the fibers at Archimedean places of arithmetic surfaces and varieties Noncommutative geometry can be expected to say something about topics of arithmetic interest because it provides the right framework for which the tools of geometry continue to make sense on spaces that are very singular and apparently very far from the world of algebraic varieties This provides a way of refining the boundary structure of certain classes of spaces that arise in the context of arithmetic geometry With a foreword written by Yuri Manin and a brief introduction to noncommutative geometry this book offers a comprehensive account of the cross fertilization between two important areas noncommutative geometry and number theory It is suitable for graduate students and researchers interested in these areas

**Noncommutative Geometry, Arithmetic, and Related Topics** Caterina Consani, Alain Connes, 2011 Mathematics Institute these essays collectively provide mathematicians and physicists with a comprehensive resource on the topic

*Noncommutative Geometry* Igor V. Nikolaev, 2022-07-18 Noncommutative geometry studies an interplay between spatial forms and algebras with non commutative multiplication This book covers the key concepts of noncommutative geometry and its applications in topology algebraic geometry and number theory Our presentation is accessible to the graduate students as well as nonexperts in the field The second edition includes two new chapters on arithmetic topology and quantum arithmetic

*Lectures on Arithmetic Noncommutative Geometry* Matilde Marcolli, 2004

**Noncommutative Geometry** Igor Nikolaev, 2017 This book covers the basics of noncommutative geometry NCG and its applications in topology algebraic geometry and number theory The author takes up the practical side of NCG and its value for other areas of mathematics A brief survey of the main parts of NCG with historical remarks bibliography and a list of exercises is included The presentation is intended for graduate students and researchers with interests in NCG but will also

serve nonexperts in the field Contents Part I Basics Model examples Categories and functors C algebras Part II Noncommutative invariants Topology Algebraic geometry Number theory Part III Brief survey of NCG Finite geometries Continuous geometries Connes geometries Index theory Jones polynomials Quantum groups Noncommutative algebraic geometry Trends in noncommutative geometry *Advances in Noncommutative Geometry* Ali Chamseddine, Caterina Consani, Nigel Higson, Masoud Khalkhali, Henri Moscovici, Guoliang Yu, 2020-01-13 This authoritative volume in honor of Alain Connes the foremost architect of Noncommutative Geometry presents the state of the art in the subject The book features an amalgam of invited survey and research papers that will no doubt be accessed read and referred to for several decades to come The pertinence and potency of new concepts and methods are concretely illustrated in each contribution Much of the content is a direct outgrowth of the Noncommutative Geometry conference held March 23 April 7 2017 in Shanghai China The conference covered the latest research and future areas of potential exploration surrounding topology and physics number theory as well as index theory and its ramifications in geometry **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 Global Analysis* Henri Moscovici, 2011 This volume represents the proceedings of the conference on Noncommutative Geometric Methods in Global Analysis held in honor of Henri Moscovici from June 29 July 4 2009 in Bonn Germany Henri Moscovici has made a number of major contributions to noncommutative geometry global analysis and representation theory This volume which includes articles by some of the leading experts in these fields provides a panoramic view of the interactions of noncommutative geometry with a variety of areas of mathematics It focuses on geometry analysis and topology of manifolds and singular spaces index theory group representation theory connections of noncommutative geometry with number theory and arithmetic geometry Hopf algebras and their cyclic cohomology *Arithmetic and Geometry Around Quantization* Özgür Ceyhan, Yu. I. Manin, Matilde Marcolli, 2010-01-12 This volume comprises both research and survey articles originating from the conference on Arithmetic and Geometry around Quantization held in Istanbul in 2006

A wide range of topics related to quantization are covered thus aiming to give a glimpse of a broad subject in very different perspectives

**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

**A Computational Non-commutative Geometry Program for Disordered Topological Insulators** Emil Prodan, 2017-03-17 This work presents a computational program based on the principles of non commutative geometry and showcases several applications to topological insulators Noncommutative geometry has been originally proposed by Jean Bellissard as a theoretical framework for the investigation of homogeneous condensed matter systems Recently this approach has been successfully applied to topological insulators where it facilitated many rigorous results concerning the stability of the topological invariants against disorder In the first part of the book the notion of a homogeneous material is introduced and the class of disordered crystals defined together with the classification table which conjectures all topological phases from this class The manuscript continues with a discussion of electrons dynamics in disordered crystals and the theory of topological invariants in the presence of strong disorder is briefly reviewed It is shown how all this can be captured in the language of noncommutative geometry using the concept of non commutative Brillouin torus and a list of known formulas for various physical response functions is presented In the second part auxiliary algebras are introduced and a canonical finite volume approximation of the non commutative Brillouin torus is developed Explicit numerical algorithms for computing generic correlation functions are discussed In the third part upper bounds on the numerical errors are derived and it is proved that the canonical finite volume approximation converges extremely fast to the thermodynamic limit Convergence tests and various applications concludes the presentation The book is intended for graduate students and researchers in numerical and mathematical physics

**Noncommutative Geometry and Global Analysis** Alain Connes, 2011

**Non-commutative Algebraic Geometry** F.M.J. van Oystaeyen, A.H.M.J. Verschoren, 2006-11-14

**Arithmetic Fundamental Groups and Noncommutative Algebra** Michael D. Fried, Yasutaka Ihara, 2002 The arithmetic and geometry of moduli spaces and their fundamental groups are a very active research area This book offers a complete overview of developments made over the last decade The papers in this volume examine the geometry of moduli spaces of curves with a function on them The main players in Part 1 are the absolute Galois group  $G_{\mathbb{Q}}$  of the algebraic numbers and its close relatives By analyzing how  $G_{\mathbb{Q}}$  acts on fundamental groups defined by Hurwitz moduli problems the authors achieve a grand generalization of Serre's program from

the 1960s Papers in Part 2 apply theta functions and configuration spaces to the study of fundamental groups over positive characteristic fields In this section several authors use Grothendieck's famous lifting results to give extensions to wildly ramified covers Properties of the fundamental groups have brought collaborations between geometers and group theorists Several Part 3 papers investigate new versions of the genus 0 problem In particular this includes results severely limiting possible monodromy groups of sphere covers Finally Part 4 papers treat Deligne's theory of Tannakian categories and arithmetic versions of the Kodaira-Spencer map This volume is geared toward graduate students and research mathematicians interested in arithmetic algebraic geometry

**Noncommutative Cosmology** Matilde Marcolli, 2017-12-26 Modified gravity models play an important role in contemporary theoretical cosmology The present book proposes a novel approach to the topic based on techniques from noncommutative geometry especially the spectral action functional as a gravity model The book discusses applications to early universe models and slow roll inflation models to the problem of cosmic topology to non isotropic cosmologies like mixmaster universes and Bianchi IX gravitational instantons and to multifractal structures in cosmology Relations between noncommutative and algebro-geometric methods in cosmology is also discussed including the occurrence of motives periods and modular forms in spectral models of gravity

**Noncommutative Geometry and the Standard Model of Elementary Particle Physics** Florian Scheck, Wend Werner, Harald Upmeyer, 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

**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

Introduction to Modern Number Theory Yu. I. Manin,Alexei A. Panchishkin,2006-03-30 This edition has been called startlingly up to date and in this corrected second printing you can be sure that it s even more contemporaneous It surveys from a unified point of view both the modern state and the trends of continuing development in various branches of number theory Illuminated by elementary problems the central ideas of modern theories are laid bare Some topics covered include non Abelian generalizations of class field theory recursive computability and Diophantine equations zeta and L functions This substantially revised and expanded new edition contains several new sections such as Wiles proof of Fermat s Last Theorem and relevant techniques coming from a synthesis of various theories

**Algebras, Rings and Modules** Michiel Hazewinkel,Nadezhda Mikhailovna Gubareni,Vladimir V. Kirichenko,2010 The main goal of this book is to present an introduction to and applications of the theory of Hopf algebras The authors also discuss some important aspects of the theory of Lie algebras The first chapter can be viewed as a primer on Lie algebras with the main goal to explain and prove the Gabriel Bernstein Gelfand Ponomarev theorem on the correspondence between the representations of Lie algebras and quivers this material has not previously appeared in book form The next two chapters are also primers on coalgebras and Hopf algebras respectively they aim specifically to give sufficient background on these topics for use in the main part of the book Chapters 4 7 are devoted to four of the most beautiful Hopf algebras currently known the Hopf algebra of symmetric functions the Hopf algebra of representations of the symmetric groups although these two are isomorphic they are very different in the aspects they bring to the forefront the Hopf algebras of the nonsymmetric and quasisymmetric functions these two are dual and both generalize the previous two and the Hopf algebra of permutations The last chapter is a survey of applications of Hopf algebras in many varied parts of mathematics and physics Unique features of the book include a new way to introduce Hopf algebras and coalgebras an extensive discussion of the many universal properties of the functor of the Witt vectors a thorough discussion of duality aspects of all the Hopf algebras mentioned emphasis on the combinatorial aspects of Hopf algebras and a survey of applications already mentioned The book also contains an extensive more than 700 entries bibliography The main goal of this book is to present an introduction to and applications of the theory of Hopf algebras The authors also discuss some important

aspects of the theory of Lie algebras The first chapter can be viewed as a primer on Lie algebras with the main goal to explain and prove the Gabriel Bernstein Gelfand Ponomarev theorem on the correspondence between the representations of Lie algebras and quivers this material has not previously appeared in book form The next two chapters are also primers on coalgebras and Hopf algebras respectively they aim specifically to give sufficient background on these topics for use in the main part of the book Chapters 4 7 are devoted to four of the most beautiful Hopf algebras currently known the Hopf algebra of symmetric functions the Hopf algebra of representations of the symmetric groups although these two are isomorphic they are very different in the aspects they bring to the forefront the Hopf algebras of the nonsymmetric and quasisymmetric functions these two are dual and both generalize the previous two and the Hopf algebra of permutations The last chapter is a survey of applications of Hopf algebras in many varied parts of mathematics and physics Unique features of the book include a new way to introduce Hopf algebras and coalgebras an extensive discussion of the many universal properties of the functor of the Witt vectors a thorough discussion of duality aspects of all the Hopf algebras mentioned emphasis on the combinatorial aspects of Hopf algebras and a survey of applications already mentioned The book also contains an extensive more than 700 entries bibliography

The book delves into Arithmetic Noncommutative Geometry. Arithmetic Noncommutative Geometry is a crucial topic that must be grasped by everyone, ranging from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Arithmetic Noncommutative Geometry, encompassing both the fundamentals and more intricate discussions.

1. The book is structured into several chapters, namely:
  - Chapter 1: Introduction to Arithmetic Noncommutative Geometry
  - Chapter 2: Essential Elements of Arithmetic Noncommutative Geometry
  - Chapter 3: Arithmetic Noncommutative Geometry in Everyday Life
  - Chapter 4: Arithmetic Noncommutative Geometry in Specific Contexts
  - Chapter 5: Conclusion
2. In chapter 1, the author will provide an overview of Arithmetic Noncommutative Geometry. This chapter will explore what Arithmetic Noncommutative Geometry is, why Arithmetic Noncommutative Geometry is vital, and how to effectively learn about Arithmetic Noncommutative Geometry.
3. In chapter 2, the author will delve into the foundational concepts of Arithmetic Noncommutative Geometry. This chapter will elucidate the essential principles that must be understood to grasp Arithmetic Noncommutative Geometry in its entirety.
4. In chapter 3, this book will examine the practical applications of Arithmetic Noncommutative Geometry in daily life. The third chapter will showcase real-world examples of how Arithmetic Noncommutative Geometry can be effectively utilized in everyday scenarios.
5. In chapter 4, the author will scrutinize the relevance of Arithmetic Noncommutative Geometry in specific contexts. The fourth chapter will explore how Arithmetic Noncommutative Geometry is applied in specialized fields, such as education, business, and technology.
6. In chapter 5, this book will draw a conclusion about Arithmetic Noncommutative Geometry. The final chapter will summarize the key points that have been discussed throughout the book.

The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. This book is highly recommended for anyone seeking to gain a comprehensive understanding of Arithmetic Noncommutative Geometry.

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