

# Complex Quantum Groups and Their Real Representations

By

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## Abstract

We define  $\ast$ -Hopf algebras  $F_{\text{an}}(SL_q(N, \mathbb{C}; e_1, \dots, e_N))$ ,  $F_{\text{an}}(O_q(N, \mathbb{C}; e_1, \dots, e_N))$  and  $F_{\text{an}}(Sp_q(n, \mathbb{C}; e_1, \dots, e_{2n}))$  as the real complexifications of  $\ast$ -Hopf algebras  $F_{\text{an}}(SU_q(N; e_1, \dots, e_N))$ ,  $F_{\text{an}}(O_q(N; e_1, \dots, e_N))$  and  $F_{\text{an}}(Sp_q(n; e_1, \dots, e_{2n}))$  of [RTF] (for  $q > 0$ ). Such construction can be done for each coquasitriangular (CQT)  $\ast$ -Hopf algebra  $A$ . The obtained object  $A^{C^*}$  is also a CQT  $\ast$ -Hopf algebra. We describe the theory of corepresentations of  $A^{C^*}$  in terms of such a theory for  $A$ .

## § 0. Introduction

Quantum groups have recently attracted the attention of many physicists and mathematicians due to their remarkable properties. Some of these properties are similar to those of usual groups, while another properties, reflecting noncommutativity of the corresponding algebras, are suitable only in the 'quantum' case. The theory is developed in two approaches. One of them ([Dr], [J]) mainly deals with quantum universal enveloping algebras, while the second ([W1]-[W3], [Dr], [RTF]) investigates algebras of functions on quantum groups. In the present paper we follow the second approach. Noncommutative algebras which we consider here are usually  $\ast$ -Hopf algebras (sometimes we consider  $C^*$ -structure on them, which makes the underlying objects topological quantum groups), so we mainly deal with 'quantum algebraic real groups'.

Simple examples of such objects are the quantum  $SU_q(2)$  groups (they are described in [W1], where the topological formulation is also given). Omitting the  $\ast$ -structure in the corresponding algebras we obtain the algebras of holomorphic polynomials on the complex quantum  $SL_q(2)$  groups. But the problem

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# Quantum Groups

**Masud Chaichian, Andrei Demichev**



## Quantum Groups:

**Quantum Groups and Their Representations** Anatoli Klimyk, Konrad Schmüdgen, 2012-12-06 This book starts with an introduction to quantum groups for the beginner and continues as a textbook for graduate students in physics and in mathematics. It can also be used as a reference by more advanced readers. The authors cover a large but well-chosen variety of subjects from the theory of quantum groups, quantized universal enveloping algebras, quantized algebras of functions, and  $q$ -deformed algebras,  $q$ -oscillator algebras, their representations and corepresentations, and noncommutative differential calculus. The book is written with potential applications in physics and mathematics in mind. The basic quantum groups and quantum algebras and their representations are given in detail and accompanied by explicit formulas. A number of topics and results from the more advanced general theory are developed and discussed.

**Introduction to Quantum Groups** George Lusztig, 2010-10-27 The quantum groups discussed in this book are the quantized enveloping algebras introduced by Drinfeld and Jimbo in 1985 or variations thereof. The theory of quantum groups has led to a new, extremely rigid structure in which the objects of the theory are provided with a canonical basis with rather remarkable properties. This book will be of interest to mathematicians working in the representation theory of Lie groups and Lie algebras, knot theorists, and to theoretical physicists and graduate students. Since large parts of the book are independent of the theory of perverse sheaves, the book could also be used as a textbook.

**Lectures on Quantum Groups** Jens Carsten Jantzen, 1996 The material is very well motivated. Of the various monographs available on quantum groups, this one seems the most suitable for most mathematicians new to the subject, will also be appreciated by a lot of those with considerably more experience. Bulletin of the London Mathematical Society. Since its origin, the theory of quantum groups has become one of the most fascinating topics of modern mathematics, with numerous applications to several, sometimes rather disparate areas, including low-dimensional topology and mathematical physics. This book is one of the first expositions that is specifically directed to students who have no previous knowledge of the subject. The only prerequisite, in addition to standard linear algebra, is some acquaintance with the classical theory of complex semisimple Lie algebras. Starting with the quantum analog of  $\mathfrak{sl}_2$ , the author carefully leads the reader through all the details necessary for full understanding of the subject, particularly emphasizing similarities and differences with the classical theory. The final chapters of the book describe the Kashiwara-Lusztig theory of so-called crystal or canonical bases in representations of complex semisimple Lie algebras. The choice of the topics and the style of exposition make Jantzen's book an excellent textbook for a one-semester course on quantum groups.

*Introduction to Quantum Groups* Masud Chaichian, Andrei Pavlovich Demichev, 1996 In the past decade, there has been an extremely rapid growth in the interest and development of quantum group theory. This book provides students and researchers with a practical introduction to the principal ideas of quantum group theory and its applications to quantum mechanical and modern field theory problems. It begins with a review of and introduction to the mathematical aspects of quantum deformation of classical groups.

Lie algebras and related objects algebras of functions on spaces differential and integral calculi In the subsequent chapters the richness of mathematical structure and power of the quantum deformation methods and non commutative geometry is illustrated on the different examples starting from the simplest quantum mechanical system harmonic oscillator and ending with actual problems of modern field theory such as the attempts to construct lattice like regularization consistent with space time Poincar symmetry and to incorporate Higgs fields in the general geometrical frame of gauge theories Graduate students and researchers studying the problems of quantum field theory particle physics and mathematical aspects of quantum symmetries will find the book of interest

*Quantum Groups and Noncommutative Geometry* Yuri I. Manin, 2018-10-11 This textbook presents the second edition of Manin's celebrated 1988 Montreal lectures which influenced a new generation of researchers in algebra to take up the study of Hopf algebras and quantum groups In this expanded write up of those lectures Manin systematically develops an approach to quantum groups as symmetry objects in noncommutative geometry in contrast to the more deformation oriented approach due to Faddeev Drinfeld and others This new edition contains an extra chapter by Theo Raedschelders and Michel Van den Bergh surveying recent work that focuses on the representation theory of a number of bi and Hopf algebras that were first introduced in Manin's lectures and have since gained a lot of attention Emphasis is placed on the Tannaka Krein formalism which further strengthens Manin's approach to symmetry and moduli objects in noncommutative geometry

*Introduction to Quantum Groups and Crystal Bases* Jin Hong, Seok-Jin Kang, 2002 The purpose of this book is to provide an elementary introduction to the theory of quantum groups and crystal bases focusing on the combinatorial aspects of the theory

*Introduction To Quantum Groups* Masud Chaichian, Andrei Demichev, 1996-11-22 In the past decade there has been an extremely rapid growth in the interest and development of quantum group theory This book provides students and researchers with a practical introduction to the principal ideas of quantum groups theory and its applications to quantum mechanical and modern field theory problems It begins with a review of and introduction to the mathematical aspects of quantum deformation of classical groups Lie algebras and related objects algebras of functions on spaces differential and integral calculi In the subsequent chapters the richness of mathematical structure and power of the quantum deformation methods and non commutative geometry is illustrated on the different examples starting from the simplest quantum mechanical system harmonic oscillator and ending with actual problems of modern field theory such as the attempts to construct lattice like regularization consistent with space time Poincar symmetry and to incorporate Higgs fields in the general geometrical frame of gauge theories Graduate students and researchers studying the problems of quantum field theory particle physics and mathematical aspects of quantum symmetries will find the book of interest

*Quantum Groups and Their Applications in Physics* Leonardo Castellani, Julius Wess, Società italiana di fisica, 1996 This book focuses on quantum groups i.e continuous deformations of Lie groups and their applications in physics These algebraic structures have been studied in the last decade by a growing number of mathematicians and physicists and are found to underlie many

physical systems of interest They do provide in fact a sort of common algebraic ground for seemingly very different physical problems As it has happened for supersymmetry the  $q$  group symmetries are bound to play a vital role in physics even in fundamental theories like gauge theory or gravity In fact  $q$  symmetry can be considered itself as a generalization of supersymmetry evident in the  $q$  commutator formulation The hope that field theories on  $q$  groups are naturally regularized begins to appear founded and opens new perspectives for quantum gravity The topics covered in this book include conformal field theories and quantum groups gauge theories of quantum groups anyons differential calculus on quantum groups and non commutative geometry poisson algebras 2 dimensional statistical models 2 1 quantum gravity quantum groups and lattice physics inhomogeneous  $q$  groups  $q$  Poincaregroup and deformed gravity and gauging of W algebras Quantum Groups Christian Kassel,2012-12-06 Here is an introduction to the theory of quantum groups with emphasis on the spectacular connections with knot theory and Drinfeld s recent fundamental contributions It presents the quantum groups attached to  $SL_2$  as well as the basic concepts of the theory of Hopf algebras Coverage also focuses on Hopf algebras that produce solutions of the Yang Baxter equation and provides an account of Drinfeld s elegant treatment of the monodromy of the Knizhnik Zamolodchikov equations *Algebras of Functions on Quantum Groups: Part I* Leonid I. Korogodski,Yan S. Soibelman,1998 The text is devoted to the study of algebras of functions on quantum groups The book includes the theory of Poisson Lie algebras quasi classical version of algebras of functions on quantum groups a description of representations of algebras of functions and the theory of quantum Weyl groups It can serve as a text for an introduction to the theory of quantum groups and is intended for graduate students and research mathematicians working in algebra representation theory and mathematical physics *Quantum Groups and Lie Theory* Andrew Pressley,2001 Leading researchers discuss quantum groups and integrable systems for graduates and researchers **A Guide to Quantum Groups** Vyjayanthi Chari,Andrew N. Pressley,1995-07-27 Since they first arose in the 1970s and early 1980s quantum groups have proved to be of great interest to mathematicians and theoretical physicists The theory of quantum groups is now well established as a fascinating chapter of representation theory and has thrown new light on many different topics notably low dimensional topology and conformal field theory The goal of this book is to give a comprehensive view of quantum groups and their applications The authors build on a self contained account of the foundations of the subject and go on to treat the more advanced aspects concisely and with detailed references to the literature Thus this book can serve both as an introduction for the newcomer and as a guide for the more experienced reader All who have an interest in the subject will welcome this unique treatment of quantum groups *Quantum Groups* Steven Shnider,Shlomo Sternberg,1993 An introduction to the field of quantum groups including topology and statistical mechanics based on lectures given at the Sackler Institute for Advanced Studies at Tel Aviv University Detailed proofs of the main results are presented and the bibliography contains more than 1260 references **Quantum Groups, Quantum Categories and Quantum Field Theory** Jürg Fröhlich,Thomas

Kerler,2006-11-15 This book reviews recent results on low dimensional quantum field theories and their connection with quantum group theory and the theory of braided balanced tensor categories It presents detailed mathematically precise introductions to these subjects and then continues with new results Among the main results are a detailed analysis of the representation theory of  $U(\mathfrak{sl}_n)$  for  $q$  a primitive root of unity and a semi simple quotient thereof a classification of braided tensor categories generated by an object of  $q$  dimension less than two and an application of these results to the theory of sectors in algebraic quantum field theory This clarifies the notion of quantized symmetries in quantum field theory The reader is expected to be familiar with basic notions and results in algebra The book is intended for research mathematicians mathematical physicists and graduate students *An Invitation to Quantum Groups and Duality* Thomas Timmermann,2008 This book provides an introduction to the theory of quantum groups with emphasis on their duality and on the setting of operator algebras Part I of the text presents the basic theory of Hopf algebras Van Daele's duality theory of algebraic quantum groups and Woronowicz's compact quantum groups staying in a purely algebraic setting Part II focuses on quantum groups in the setting of operator algebras Woronowicz's compact quantum groups are treated in the setting of  $C^*$  algebras and the fundamental multiplicative unitaries of Baaj and Skandalis are studied in detail An outline of Kustermans and Vaes comprehensive theory of locally compact quantum groups completes this part Part III leads to selected topics such as coactions Baaj Skandalis duality and approaches to quantum groupoids in the setting of operator algebras The book is addressed to graduate students and non experts from other fields Only basic knowledge of multi linear algebra is required for the first part while the second and third part assume some familiarity with Hilbert spaces  $C^*$  algebras and von Neumann algebras Introduction to Quantum Groups Teo Banica,2023-01-01 This book introduces the reader to quantum groups focusing on the simplest ones namely the closed subgroups of the free unitary group Although such quantum groups are quite easy to understand mathematically interesting examples abound including all classical Lie groups their free versions half liberations other intermediate liberations anticommutation twists the duals of finitely generated discrete groups quantum permutation groups quantum reflection groups quantum symmetry groups of finite graphs and more The book is written in textbook style with its contents roughly covering a one year graduate course Besides exercises the author has included many remarks comments and pieces of advice with the lone reader in mind The prerequisites are basic algebra analysis and probability and a certain familiarity with complex analysis and measure theory Organized in four parts the book begins with the foundations of the theory due to Woronowicz comprising axioms Haar measure Peter Weyl theory Tannakian duality and basic Brauer theorems The core of the book its second and third parts focus on the main examples first in the continuous case and then in the discrete case The fourth and last part is an introduction to selected research topics such as toral subgroups homogeneous spaces and matrix models Introduction to Quantum Groups offers a compelling introduction to quantum groups from the simplest examples to research level topics Quantum Groups Vladimir K. Dobrev,2017-07-10

With applications in quantum field theory general relativity and elementary particle physics this three volume work studies the invariance of differential operators under Lie algebras quantum groups and superalgebras This second volume covers quantum groups in their two main manifestations quantum algebras and matrix quantum groups The exposition covers both the general aspects of these and a great variety of concrete explicitly presented examples The invariant  $q$  difference operators are introduced mainly using representations of quantum algebras on their dual matrix quantum groups as carrier spaces This is the first book that covers the title matter applied to quantum groups Contents Quantum Groups and Quantum Algebras Highest Weight Modules over Quantum Algebras Positive Energy Representations of Noncompact Quantum Algebras Duality for Quantum Groups Invariant  $q$  Difference Operators Invariant  $q$  Difference Operators Related to  $GL_q(n, q)$  Maxwell Equations Hierarchies

**Quantum Groups and Their Primitive Ideals** Anthony Joseph, 2012-12-06 by a more general quadratic algebra possibly obtained by deformation and then to derive  $R_q G$  by requiring it to possess the latter as a comodule A third principle is to focus attention on the tensor structure of the category of modules This means of course just defining an algebra structure on  $R_q G$  but this is to be done in a very specific manner Concretely the category is required to be braided and this forces the existence of an  $R$  matrix satisfying in particular the quantum Yang Baxter equation and from which the algebra structure of  $R_q G$  can be written down Finally there was a search for a perfectly self dual model for  $R_q G$  which would then be isomorphic to  $U_q g$  Apparently this failed but V G Drinfeld found that it could be essentially made to work for the Borel part of  $U_q g$  denoted  $U_b$  and further found a general construction the Drinfeld double  $q$  mirroring a Lie bialgebra This gives  $U_q g$  up to passage to a quotient One of the most remarkable aspects of the above superficially different approaches is their extraordinary intercoherence In particular they essentially all lead for  $G$  semisimple to the same and hence canonical objects  $R_q G$  and  $U_q g$  though this epithet may as yet be premature

Quantum Groups Ross Street, 2007-01-18 Algebra has moved well beyond the topics discussed in standard undergraduate texts on modern algebra Those books typically dealt with algebraic structures such as groups rings and fields still very important concepts However Quantum Groups A Path to Current Algebra is written for the reader at ease with at least one such structure and keen to learn algebraic concepts and techniques A key to understanding these new developments is categorical duality A quantum group is a vector space with structure Part of the structure is standard a multiplication making it an algebra Another part is not in those standard books at all a comultiplication which is dual to multiplication in the precise sense of category theory making it a coalgebra While coalgebras bialgebras and Hopf algebras have been around for half a century the term quantum group along with revolutionary new examples was launched by Drinfeld in 1986

**Quantum Groups** Benjamin Enriquez, 2008 The volume starts with a lecture course by P Etingof on tensor categories notes by D Calaque This course is an introduction to tensor categories leading to topics of recent research such as realizability of fusion rings Ocneanu rigidity module categories weak Hopf algebras Morita theory for tensor categories lifting theory categorical

dimensions Frobenius Perron dimensions and the classification of tensor categories The remainder of the book consists of three detailed expositions on associators and the Vassiliev invariants of knots classical and quantum integrable systems and elliptic algebras and the groups of algebra automorphisms of quantum groups The preface puts the results presented in perspective Directed at research mathematicians and theoretical physicists as well as graduate students the volume gives an overview of the ongoing research in the domain of quantum groups an important subject of current mathematical physics

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