

Mathematical Physics Studies

Damien Calaque  
Thomas Strobl *Editors*

# Mathematical Aspects of Quantum Field Theories

 Springer

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## Mathematical Physics Studies

**Valter Moretti**



## **Mathematical Aspects Of Quantum Field Theories Mathematical Physics Studies:**

Mathematical Aspects of Quantum Field Theories Damien Calaque, Thomas Strobl, 2015-01-06 Despite its long history and stunning experimental successes the mathematical foundation of perturbative quantum field theory is still a subject of ongoing research This book aims at presenting some of the most recent advances in the field and at reflecting the diversity of approaches and tools invented and currently employed Both leading experts and comparative newcomers to the field present their latest findings helping readers to gain a better understanding of not only quantum but also classical field theories Though the book offers a valuable resource for mathematicians and physicists alike the focus is more on mathematical developments This volume consists of four parts The first Part covers local aspects of perturbative quantum field theory with an emphasis on the axiomatization of the algebra behind the operator product expansion The second Part highlights Chern Simons gauge theories while the third examines semi classical field theories In closing Part 4 addresses factorization homology and factorization algebras *Mathematical Aspects of Quantum Field Theory* Edson de Faria, Wellington de Melo, 2010-08-12 Over the last century quantum field theory has made a significant impact on the formulation and solution of mathematical problems and inspired powerful advances in pure mathematics However most accounts are written by physicists and mathematicians struggle to find clear definitions and statements of the concepts involved This graduate level introduction presents the basic ideas and tools from quantum field theory to a mathematical audience Topics include classical and quantum mechanics classical field theory quantization of classical fields perturbative quantum field theory renormalization and the standard model The material is also accessible to physicists seeking a better understanding of the mathematical background providing the necessary tools from differential geometry on such topics as connections and gauge fields vector and spinor bundles symmetries and group representations **Mathematics of Quantization and Quantum Fields** Jan Dereziński, Christian Gérard, 2023-02-09 This 2013 book now OA offers a definitive review of mathematical aspects of quantization and quantum field theory Advances in Algebraic Quantum Field Theory Romeo Brunetti, Claudio Dappiaggi, Klaus Fredenhagen, Jakob Yngvason, 2015-09-04 This text focuses on the algebraic formulation of quantum field theory from the introductory aspects to the applications to concrete problems of physical interest The book is divided in thematic chapters covering both introductory and more advanced topics These include the algebraic perturbative approach to interacting quantum field theories algebraic quantum field theory on curved spacetimes from its structural aspects to the applications in cosmology and to the role of quantum spacetimes algebraic conformal field theory the Kitaev s quantum double model from the point of view of local quantum physics and constructive aspects in relation to integrable models and deformation techniques The book is addressed to master and graduate students both in mathematics and in physics who are interested in learning the structural aspects and the applications of algebraic quantum field theory Spectral Theory and Quantum Mechanics Valter Moretti, 2018-01-30 This book discusses the mathematical foundations of quantum theories It

offers an introductory text on linear functional analysis with a focus on Hilbert spaces highlighting the spectral theory features that are relevant in physics After exploring physical phenomenology it then turns its attention to the formal and logical aspects of the theory Further this Second Edition collects in one volume a number of useful rigorous results on the mathematical structure of quantum mechanics focusing in particular on von Neumann algebras Superselection rules the various notions of Quantum Symmetry and Symmetry Groups and including a number of fundamental results on the algebraic formulation of quantum theories Intended for Master s and PhD students both in physics and mathematics the material is designed to be self contained it includes a summary of point set topology and abstract measure theory together with an appendix on differential geometry The book also benefits established researchers by organizing and presenting the profusion of advanced material disseminated in the literature Most chapters are accompanied by exercises many of which are solved explicitly

**Spectral Theory and Quantum Mechanics** Valter Moretti, 2013-04-02 This book pursues the accurate study of the mathematical foundations of Quantum Theories It may be considered an introductory text on linear functional analysis with a focus on Hilbert spaces Specific attention is given to spectral theory features that are relevant in physics Having left the physical phenomenology in the background it is the formal and logical aspects of the theory that are privileged Another not lesser purpose is to collect in one place a number of useful rigorous statements on the mathematical structure of Quantum Mechanics including some elementary yet fundamental results on the Algebraic Formulation of Quantum Theories In the attempt to reach out to Master s or PhD students both in physics and mathematics the material is designed to be self contained it includes a summary of point set topology and abstract measure theory together with an appendix on differential geometry The book should benefit established researchers to organise and present the profusion of advanced material disseminated in the literature Most chapters are accompanied by exercises many of which are solved explicitly

Statistical Approach to Quantum Field Theory Andreas Wipf, 2021-10-25 This new expanded second edition has been totally revised and corrected The reader finds two complete new chapters One covers the exact solution of the finite temperature Schwinger model with periodic boundary conditions This simple model supports instanton solutions similarly as QCD and allows for a detailed discussion of topological sectors in gauge theories the anomaly induced breaking of chiral symmetry and the intriguing role of fermionic zero modes The other new chapter is devoted to interacting fermions at finite fermion density and finite temperature Such low dimensional models are used to describe long energy properties of Dirac type materials in condensed matter physics The large  $N$  solutions of the Gross Neveu Nambu Jona Lasinio and Thirring models are presented in great detail where  $N$  denotes the number of fermion flavors Towards the end of the book corrections to the large  $N$  solution and simulation results of a finite number of fermion flavors are presented Further problems are added at the end of each chapter in order to guide the reader to a deeper understanding of the presented topics This book is meant for advanced students and young researchers who want to acquire the necessary tools and experience to produce research results in the

statistical approach to Quantum Field Theory      *Topological Quantum Field Theory and Four Manifolds* Jose Labastida, Marcos Marino, 2005-02-14 The emergence of topological quantum field theory has been one of the most important breakthroughs which have occurred in the context of mathematical physics in the last century a century characterized by independent developments of the main ideas in both disciplines physics and mathematics which has concluded with two decades of strong interaction between them where physics as in previous centuries has acted as a source of new mathematics Topological quantum field theories constitute the core of these phenomena although the main driving force behind it has been the enormous effort made in theoretical particle physics to understand string theory as a theory able to unify the four fundamental interactions observed in nature These theories set up a new realm where both disciplines profit from each other Although the most striking results have appeared on the mathematical side theoretical physics has clearly also benefited since the corresponding developments have helped better to understand aspects of the fundamentals of field and string theory      **Mathematical Aspects of Quantum Field Theory** Edson de Faria, Wellington de Melo, 2010-08-12 Over the last century quantum field theory has made a significant impact on the formulation and solution of mathematical problems and inspired powerful advances in pure mathematics However most accounts are written by physicists and mathematicians struggle to find clear definitions and statements of the concepts involved This graduate level introduction presents the basic ideas and tools from quantum field theory to a mathematical audience Topics include classical and quantum mechanics classical field theory quantization of classical fields perturbative quantum field theory renormalization and the standard model The material is also accessible to physicists seeking a better understanding of the mathematical background providing the necessary tools from differential geometry on such topics as connections and gauge fields vector and spinor bundles symmetries and group representations      Non-perturbative Quantum Field Theory Jürg Fröhlich, 1992 A collection of 22 reprints of Fröhlich's articles on non perturbative aspects of quantum field theory more than half of them of a review character on topics in phase transitions and continuous symmetry breaking non perturbative quantization of topological solitons gauge theories including the infrared problem in quantum electrodynamics random geometry quantum gravity and strings and low dimensional QFT two dimensional conformal field theory three dimensional gauge theories No index Paper edition unseen 48 Annotation copyrighted by Book News Inc Portland OR      *Analysis On Fock Spaces And Mathematical Theory Of Quantum Fields: An Introduction To Mathematical Analysis Of Quantum Fields* Asao Arai, 2017-12-20 This book provides a comprehensive introduction to Fock space theory and its applications to mathematical quantum field theory The first half of the book Part I is devoted to detailed descriptions of analysis on abstract Fock spaces full Fock space boson Fock space fermion Fock space and boson fermion Fock space It includes the mathematics of second quantization representation theory of canonical commutation relations and canonical anti commutation relations Bogoliubov transformations infinite dimensional Dirac operators and supersymmetric quantum field in an abstract form The

second half of the book Part II covers applications of the mathematical theories in Part I to quantum field theory Four kinds of free quantum fields are constructed and detailed analyses are made A simple interacting quantum field model called the van Hove model is fully analyzed in an abstract form Moreover a list of interacting quantum field models is presented and a short description to each model is given To graduate students in mathematics or physics who are interested in the mathematical aspects of quantum field theory this book is a good introductory text It is also well suited for self study and will provide readers a firm foundation of knowledge and mathematical techniques for reading more advanced books and current research articles in the field of mathematical analysis on quantum fields Also numerous problems are added to aid readers to develop a deeper understanding of the field

**Advances in Algebraic Quantum Field Theory** Romeo Brunetti, Claudio Dappiaggi, Klaus Fredenhagen, Jakob Yngvason, 2015 This text focuses on the algebraic formulation of quantum field theory from the introductory aspects to the applications to concrete problems of physical interest The book is divided in thematic chapters covering both introductory and more advanced topics These include the algebraic perturbative approach to interacting quantum field theories algebraic quantum field theory on curved spacetimes from its structural aspects to the applications in cosmology and to the role of quantum spacetimes algebraic conformal field theory the Kitaev's quantum double model from the point of view of local quantum physics and constructive aspects in relation to integrable models and deformation techniques The book is addressed to master and graduate students both in mathematics and in physics who are interested in learning the structural aspects and the applications of algebraic quantum field theory

Scattering Amplitudes in Quantum Field Theory Simon Badger, Johannes Henn, Jan Christoph Plefka, Simone Zoia, 2023-12-31 This open access book bridges a gap between introductory Quantum Field Theory QFT courses and state of the art research in scattering amplitudes It covers the path from basic definitions of QFT to amplitudes which are relevant for processes in the Standard Model of particle physics The book begins with a concise yet self contained introduction to QFT including perturbative quantum gravity It then presents modern methods for calculating scattering amplitudes focusing on tree level amplitudes loop level integrands and loop integration techniques These methods help to reveal intriguing relations between gauge and gravity amplitudes and are of increasing importance for obtaining high precision predictions for collider experiments such as those at the Large Hadron Collider as well as for foundational mathematical physics studies in QFT including recent applications to gravitational wave physics These course tested lecture notes include numerous exercises with solutions Requiring only minimal knowledge of QFT they are well suited for MSc and PhD students as a preparation for research projects in theoretical particle physics They can be used as a one semester graduate level course or as a self study guide for researchers interested in fundamental aspects of quantum field theory

Quantum and Non-Commutative Analysis Huzihiro Araki, Keiichi R. Ito, Akitaka Kishimoto, Izumi Ojima, 2013-04-17 In the past decade there has been a sudden and vigorous development in a number of research areas in mathematics and mathematical physics such as theory of operator algebras

knot theory theory of manifolds infinite dimensional Lie algebras and quantum groups as a new topics etc on the side of mathematics quantum field theory and statistical mechanics on the side of mathematical physics The new development is characterized by very strong relations and interactions between different research areas which were hitherto considered as remotely related Focussing on these new developments in mathematical physics and theory of operator algebras the International Oji Seminar on Quantum Analysis was held at the Kansai Seminar House Kyoto JAPAN during June 25 29 1992 by a generous sponsorship of the Japan Society for the Promotion of Science and the Fujihara Foundation of Science as a workshop of relatively small number of about 50 invited participants This was followed by an open Symposium at RIMS described below by its organizer A Kishimoto The Oji Seminar began with two key note addresses one by V F R Jones on Spin Models in Knot Theory and von Neumann Algebras and by A Jaffe on Where Quantum Field Theory Has Led Subsequently topics such as Subfactors and Sector Theory Solvable Models of Statistical Mechanics Quantum Field Theory Quantum Groups and Renormalization Group Approach are discussed Towards the end a panel discussion on Where Should Quantum Analysis Go was held

**Mathematical Physics in Mathematics and Physics** Roberto Longo, 2001 The beauty and the mystery surrounding the interplay between mathematics and physics is captured by E Wigner's famous expression The unreasonable effectiveness of mathematics We don't know why but physical laws are described by mathematics and good mathematics sooner or later finds applications in physics often in a surprising way In this sense mathematical physics is a very old subject as Egyptian Phoenician or Greek history tells us But mathematical physics is a very modern subject as any working mathematician or physicist can witness It is a challenging discipline that has to provide results of interest for both mathematics and physics Ideas and motivations from both these sciences give it a vitality and freshness that is difficult to find anywhere else One of the big physical revolutions in the twentieth century quantum physics opened a new magnificent era for this interplay With the appearance of noncommutative analysis the role of classical calculus has been taken by commutation relations a subject still growing in an astonishing way A good example where mathematical physics showed its power beauty and interdisciplinary character is the Doplicher Haag Roberts analysis of superselection sectors in the late 1960s Not only did this theory explain the origin of statistics and classify it but year after year new connections have merged for example with Tomita Takesaki modular theory Jones theory of subfactors and Doplicher Roberts abstract duality for compact groups This volume contains the proceedings of the conference Mathematical Physics in Mathematics and Physics dedicated to Sergio Doplicher and John E Roberts held in Siena Italy The articles offer current research in various fields of mathematical physics primarily concerning quantum aspects of operator algebras

**Analytic Aspects of Quantum Fields** Andrei A. Bytsenko, 2003-01-01 One of the aims of this book is to explain in a basic manner the seemingly difficult issues of mathematical structure using some specific examples as a guide In each of the cases considered a comprehensible physical problem is approached to which the corresponding mathematical scheme is applied its usefulness being duly demonstrated

The authors try to fill the gap that always exists between the physics of quantum field theories and the mathematical methods best suited for its formulation which are increasingly demanding on the mathematical ability of the physicist

Contents Survey of Path Integral Quantization and Regularization Techniques The Zeta Function Regularization Method Generalized Spectra and Spectral Functions on Non Commutative Spaces Spectral Functions of Laplace Operator on Locally Symmetric Spaces Spinor Fields Field Fluctuations and Related Variances The Multiplicative Anomaly Applications of the Multiplicative Anomaly The Casimir Effect Readership Mathematical and high energy physicists     Fundamental Mathematical Structures of Quantum Theory Valter Moretti, 2019-06-20 This textbook presents in a concise and self contained way the advanced fundamental mathematical structures in quantum theory It is based on lectures prepared for a 6 months course for MSc students The reader is introduced to the beautiful interconnection between logic lattice theory general probability theory and general spectral theory including the basic theory of von Neumann algebras and of the algebraic formulation naturally arising in the study of the mathematical machinery of quantum theories Some general results concerning hidden variable interpretations of QM such as Gleason's and the Kochen Specker theorems and the related notions of realism and non contextuality are carefully discussed This is done also in relation with the famous Bell BCHSH inequality concerning local causality Written in a didactic style this book includes many examples and solved exercises The work is organized as follows Chapter 1 reviews some elementary facts and properties of quantum systems Chapter 2 and 3 present the main results of spectral analysis in complex Hilbert spaces Chapter 4 introduces the point of view of the orthomodular lattices theory Quantum theory from this perspective turns out to be the probability measure theory on the non Boolean lattice of elementary observables and Gleason's theorem characterizes all these measures Chapter 5 deals with some philosophical and interpretative aspects of quantum theory like hidden variable formulations of QM The Kochen Specker theorem and its implications are analyzed also in relation to the BCHSH inequality entanglement realism locality and non contextuality Chapter 6 focuses on the algebra of observables also in the presence of superselection rules introducing the notion of von Neumann algebra Chapter 7 offers the idea of groups of quantum symmetry in particular illustrated in terms of Wigner and Kadison theorems Chapter 8 deals with the elementary ideas and results of the so called algebraic formulation of quantum theories in terms of both algebras and C algebras This book should appeal to a dual readership on one hand mathematicians that wish to acquire the tools that unlock the physical aspects of quantum theories on the other physicists eager to solidify their understanding of the mathematical scaffolding of quantum theories     **Perturbative Algebraic Quantum Field Theory** Kasia Rejzner, 2016-03-16 Perturbative Algebraic Quantum Field Theory pAQFT the subject of this book is a complete and mathematically rigorous treatment of perturbative quantum field theory pQFT that doesn't require the use of divergent quantities and works on a large class of Lorentzian manifolds We discuss in detail the examples of scalar fields gauge theories and the effective quantum gravity pQFT models describe a wide range of physical phenomena and have

remarkable agreement with experimental results Despite this success the theory suffers from many conceptual problems pAQFT is a good candidate to solve many if not all of these conceptual problems Chapters 1 3 provide some background in mathematics and physics Chapter 4 concerns classical theory of the scalar field which is subsequently quantized in chapters 5 and 6 Chapter 7 covers gauge theory and chapter 8 discusses effective quantum gravity The book aims to be accessible to researchers and graduate students who are interested in the mathematical foundations of pQFT

*Factorization Algebras in Quantum Field Theory* Kevin Costello, Owen Gwilliam, 2017 This first volume develops factorization algebras with a focus upon examples exhibiting their use in field theory which will be useful for researchers and graduates

**Representation Theory, Mathematical Physics, and Integrable Systems** Anton Alekseev, Edward Frenkel, Marc Rosso, Ben Webster, Milen Yakimov, 2022-02-05 Over the course of his distinguished career Nicolai Reshetikhin has made a number of groundbreaking contributions in several fields including representation theory integrable systems and topology The chapters in this volume compiled on the occasion of his 60th birthday are written by distinguished mathematicians and physicists and pay tribute to his many significant and lasting achievements Covering the latest developments at the interface of noncommutative algebra differential and algebraic geometry and perspectives arising from physics this volume explores topics such as the development of new and powerful knot invariants new perspectives on enumerative geometry and string theory and the introduction of cluster algebra and categorification techniques into a broad range of areas Chapters will also cover novel applications of representation theory to random matrix theory exactly solvable models in statistical mechanics and integrable hierarchies The recent progress in the mathematical and physical aspects of deformation quantization and tensor categories is also addressed Representation Theory Mathematical Physics and Integrable Systems will be of interest to a wide audience of mathematicians interested in these areas and the connections between them ranging from graduate students to junior mid career and senior researchers

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