Preface

This volume originates from the international conference *Applications of Noncommutative Geometry to Gauge Theories, Field Theories, and Quantum Space-Time*, held from April 7–11, 2025 at the Centre International de Rencontres Mathématiques (CIRM), Marseille, France. The conference brought together mathematicians and theoretical physicists working at the intersection of geometry, quantum theory, gravitation, and fundamental interactions, with the aim of exploring recent developments and perspectives in noncommutative geometry and its applications to modern physics.

The conference was organized by Roberta Anna Iseppi (University of Göttingen), Pierre Martinetti (UniGe, INFN), Thierry Masson (CNRS, Aix-Marseille Université), Gaston Nieuviarts (University of Genova), and Patrizia Vitale (University of Naples Federico II). It benefited from the support of several institutions and scientific networks, including the ARCHIMEDES Project, Aix-Marseille Université, the Centre International de Rencontres Mathématiques (CIRM), the Centre de Physique Théorique (CPT), as well as the European Cooperation in Science and Technology (ECOST).

Understanding the nature of space and time remains one of the central challenges of contemporary mathematics and theoretical physics. Since the emergence of quantum mechanics and general relativity, the reconciliation of the spectral description of physical phenomena with the geometric structure of spacetime has motivated profound developments in both disciplines. In this context, noncommutative geometry has progressively established itself as a powerful framework capable of extending geometric ideas beyond the classical setting of smooth manifolds and incorporating the spectral and quantum aspects of geometry.

The idea that spacetime coordinates may become noncommutative at very short distances dates back to the early developments of quantum theory. Over the past decades, noncommutative geometry has evolved into a rich and active field connecting operator algebras, topology, index theory, quantum field theory, gravitation, deformation quantization, and high-energy physics. It has provided new perspectives on the spectral formulation of the Standard Model, generalized notions of symmetry, quantum spacetime, and possible approaches to quantum gravity.

The aim of the conference was to encourage exchanges between these different directions and to highlight recent progress in the interplay between noncommutative geometry and physics, notably:

- the spectral formulation of the Standard Model of fundamental interactions and the emergence of an internal geometry of spacetime;
- generalized notions of spacetime symmetries and their consequences for physics;
- new frameworks for gauge theories and quantum field theories;

- geometric and spectral approaches to quantum spacetime and quantum gravity.

The contributions collected in this volume originate from a series of lectures delivered by the authors and editors during the conference. They reflect the diversity and vitality of current research in the field, addressing both foundational questions and concrete mathematical constructions, ranging from spectral triples and index theory to deformation quantization, quantum field theory, random geometries, and arithmetic aspects of spectral theory. Together, these works illustrate the capacity of noncommutative geometry to bring into dialogue analytic, algebraic, geometric, arithmetic, and physical ideas within a common conceptual framework.

This volume also acknowledges the support of the ARCHIMEDES Project, whose objective is to promote fundamental research and to encourage exchanges within the international scientific community. Through its support for research, training, and the dissemination of knowledge, the project contributes to the development of collaborative work at the interface of mathematics and theoretical physics.

The editors warmly thank all participants, lecturers, contributors, and supporting institutions whose efforts made both the conference and this volume possible. We also express our gratitude to the staff of CIRM for providing an exceptional scientific environment that greatly contributed to the success of the meeting.

We would also like to thank EMS Press, and especially the Editorial Director Apostolos Damialis, the Head of Production Gabriella Böhm, Sara Tohamy, and the entire production team for their efficiency, availability, professionalism, and kindness throughout this collaboration.

Finally, we hope that this volume will serve not only as a record of the conference, but also as a useful reference for researchers and students interested in noncommutative geometry, mathematical physics, and the ongoing exploration of the geometric structures underlying quantum theory and spacetime.

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