Preface

Loops have been used as a tool to study classical and quantum Yang–Mills theory since the work of Mandelstam in the early 1960s. They have led to many insights concerning the non-perturbative dynamics of the theory including the issue of confinement and the lattice formulation. Since the inception of the Asthekar new variables, loop techniques have also found important applications in quantum gravity. Due to the diffeomorphism invariance of the theory they have led to surprising connections with knot theory and topological field theories.

The intention in this book is to present several of these results in a common framework and language. In particular it is an attempt to combine ideas developed some time ago in the context of Yang–Mills theories with the recent applications in quantum gravity. It should be emphasized that our treatment of Yang–Mills theories only covers a small part of all results obtained with loops: that which seems of most relevance for applications in gravity.

This book should allow people from outside the field to gain access in a pedagogical way to the current state of the art. Moreover, it allows experts within this wide field with heterogeneous backgrounds to learn about specific results outside their main area of expertise and as a reference volume. It should be well suited as an introductory guide for graduate students who want to get started in the subject.

Subjects in this area are being developed at two different levels: one more "mathematical", related to constructive quantum field theory and the other more "physical" in which several subtleties are ignored in order to gain rapid insight into the theory. This book will largely concentrate on this latter approach. We will present in some detail the mathematics underlying loops but only at the level needed for a physicist to operate with the resulting formalism.

Due to the rapid development of these ideas in recent times we wrote

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this book with expediency in mind in order to offer it to the public as soon as possible. We ask readers to forgive any notational and conventions errors that might have arisen in this process. In spite of our efforts to deliver the book expediently, during the time it took to write it the field has already evolved. Although we have kept the manuscript updated, some aspects of the presentation may not be completely in line with current thinking. For instance, the recently pinpointed convergence issues of extended loops and their possible solutions are only briefly mentioned. The rapid development over the last few months of a measure theory in infinite-dimensional spaces and its impact on a rigorous definition of a loop representation is only briefly discussed in chapter 3 and its implications for later chapters are ignored. A similar remark applies to the recent developments concerning the solution of the Mandelstam constraints in terms of spin network states and the possibility of having a basis of independent loop states. We have tried to present a current outlook from our perspective in chapter 12, including very recent references to work in progress.

Many people have contributed to make this book possible. We cannot attempt to exhaustively list all the colleagues from which we have benefited through discussions and interactions. We like to thank the colleagues with which we have had a closer interaction and whose ideas have certainly left an imprint on this book: Abhay Ashtekar, Bernd Brügmann, Cayetano Di Bartolo, Jorge Griego, Jerzy Lewandowski, Jose Mourão, Carlo Rovelli, Lee Smolin and Antoni Trias. We also wish to thank Abhay Ashtekar, John Baez, John Baker, José Mourão, Peter Peldán, Carlo Rovelli, Thorsten Schwander, José Antonio Zapata and especially Bernd Brügmann and Jerzy Lewandowski for many useful comments about the manuscript.

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