Preface

Much effort in theoretical physics goes towards building mathematical models that can describe as a wide a variety of physical systems as possible. To build such models, it is necessary to introduce just the right amount of formalism: the mathematics must be able to capture the essential properties of the physical system, while keeping the amount of mathematical structure which does not have a direct physical interpretation to a minimum.

This book is concerned with the description of physical systems in terms of *ensembles on configuration space*. As will be seen, this is an approach which introduces very few physical and mathematical assumptions. As a consequence, the formalism has wide applicability: it can be used to describe physical systems that are deterministic as well as systems subject to uncertainty; discrete systems, particles, and field theories; classical and quantum theories. It also allows for theories that are difficult to formulate using other approaches, such as hybrid quantum-classical theories where there is an interaction between quantum and classical sectors, including the coupling of quantum matter to classical gravity. Finally, it provides insights into classical and quantum physics that not only lead to unified approaches to concepts such as thermodynamics, weak values, locality and superselection, but to novel reconstructions of quantum theory from physical and geometric axioms.

We therefore believe that a detailed account of the formalism and the physics of ensembles on configuration space is valuable in providing a useful (and beautiful) reformulation of existing theories, and in suggesting various generalisations and directions for formulating new theories, and hope that ideas from this book will be incorporated into the standard toolkit of theoretical physicists.

The book is structured into four main parts. Part I deals with general concepts and properties of ensembles on configuration space. Part II examines how quantum mechanics emerges naturally from three very different axiomatic scenarios, based respectively on an exact uncertainty principle, information geometry on configuration space, and local representations of rotations on discrete configuration spaces. Part III develops a theory of hybrid quantum-classical interactions, which overcomes various no-go theorems in the literature and provides an explicit model of interaction between quantum systems and classical measuring apparatuses. Finally, Part IV extends these ideas to show how quantum fields can be consistently coupled to classical gravity. While much of the material is based on publications by the authors and colleagues over the past 15 years or so, many results are presented here for the first time.

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Brisbane, Australia — Michael J.W. Hall
Braunschweig, Germany — Marcel Reginatto
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