Preface

The monograph is intended to provide an overview of the basic concepts and methods in the emerging area of quantum plasmas. In the near future, quantum effects in plasmas tend to be unavoidable, specially in high density scenarios such as in the next-generation intense laser-solid density plasma experiment or in compact astrophysics objects. Moreover, quantum plasmas are in the forefront of many intriguing questions around the transition from microscopic to macroscopic modeling of charged particle systems in general. In addition, the methods used for quantum plasmas can be readily translated to related areas which are currently pushing forward the frontiers of plasma science. This is valid, in particular, when using Wigner function tools for strongly coupled ultra-cold and Rydberg plasmas.

In recent years, the *quantum hydrodynamic model* became popular as a simplified but not simplistic approach for quantum plasmas. In particular, the nonlinear aspects of quantum plasmas are much more accessible using a fluid description, in comparison with kinetic theory. The aim of this book is to give an account of the basic developments on the hydrodynamic paradigm for quantum plasma problems, readable by a broad audience. Therefore, the proofs and mathematical calculations are given with some detail, usually not shown in the papers of the literature, due to brevity needs. Hence, some "tricks" needed to achieve most mathematical results are discussed here and there. This is the case, for instance, in the derivation in Chap. 2 of the evolution equation for the reduced one-particle Wigner function. Further examples, as well as new developments, appear in the exercises at the end of each chapter.

In the same context, in the Introduction, a very brief account on classical and quantum plasmas is offered. Here, the differences and similarities of the classical and quantum cases are stressed. We hope that in this way the book can become valuable for readers not necessarily fully acquainted with theoretical plasma physics and quantum mechanics. However, some level of knowledge is presumed: basic statistical mechanics and nonrelativistic quantum mechanics. Some familiarity with plasma methods is also advisable, although not mandatory.

The monograph is not intended to be encyclopedic. Rather, the chosen topics reflect the particular experience of the author. Nevertheless, there is a scientifically arguable reason for the sequence of contents, so as to make the book as self-contained as possible. Hence, the first chapter is an overview of classical and quantum plasmas. Chapter 2 is dedicated to the basic kinetic model for quantum plasmas, namely the Wigner–Poisson system. Here, the essentials on Wigner functions and electrostatic quantum plasmas are discussed. Chapter 3 dealt with the first attempt to a fluid model for quantum plasmas, based on the quantum Dawson (or multistream) model. The nontrivial peculiarities of the stability problem of streaming equilibria in quantum plasmas are analyzed. In Chap. 4, the quantum hydrodynamic model for plasmas is derived. The merits and intrinsic approximations of this approach are addressed. Chapter 5 is dedicated to the quantum ion-acoustic waves as described by the quantum hydrodynamic model. Chapter 6 generalize the quantum hydrodynamic model to include magnetic fields. The associated magnetohydrodynamic equations are then derived. Chapters 7 and 8 apply the quantum hydrodynamic equations to the nonlinear interaction between Langmuir and ion-acoustic waves in a quantum plasma. The corresponding quantum Zakharov system is considered in one (Chap. 7) and three (Chap. 8) spatial dimensions. In Chap. 9, a moment method approach provides an alternative macroscopic description for quantum plasmas, in the electrostatic and electromagnetic cases. The above sequence of topics goes in the sense of increasing complexity.

Along the history of plasma physics, most nature and laboratory plasmas fit in density and temperature regimes so that classical descriptions can be safely employed. With the ongoing miniaturization and the experimental assessment of new parameter regimes, however, the need to take into account quantum effects in many-body charged particle systems is becoming a reality. Hopefully, this monograph can be useful against the prejudice according to which plasma science is necessarily classical. In this manner, we expect to encourage researchers to work in this basically unexplored emerging field, whose consequences are for the moment largely unknown.

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