Preface

The Fermionic many-body problem has been a major theme in physics since the early days of quantum mechanics. Its applications span the range from the microscale in nuclei and atoms to the macroscopic scale in condensed matter physics and even beyond e.g. in the physics of neutron stars. Within the last ten years, a completely new area has developed, in which some of the most basic models that have been used to deal with the fermionic many-body problem can be studied in an unprecedented clean manner: ultracold atoms, whose interactions can be tuned over a wide range via Feshbach resonances. Despite the extreme diluteness of these gaseous systems, ultracold atoms allow to reach a regime of strong interactions once the scattering length exceeds the average interparticle distance. In particular, ultracold Fermi gases near a Fesbach resonance provide a perfect realization of the crossover between superfluids of the BCS type and a Bose–Einstein-Condensate of strongly bound pairs, a subject that had been discussed theoretically for decades but had never been accessible in practice before. The special case of the unitary gas at infinite scattering length exhibits additional symmetries like scale and conformal invariance that have lead to new developments in both many-body physics and field theory. Moreover, the universality that is connected with the fact that the interaction range is much shorter than the average interparticle distance implies that results obtained with ultracold gases also apply in a quite different context, e.g. to strongly interacting nucleons in the core of neutron stars. Ultracold atoms thus provide a novel model system in which basic questions in many-body physics can be addressed and—most importantly—a quantitative comparison between theory and experiment is possible. The results thus serve as a benchmark for judging the accuracy of methods used in many-body theory as applied to the more complex problems that are of relevance in condensed matter and nuclear physics. Ultracold atoms have opened a completely new area in many-body physics whose implications reach far beyond the particular context of dilute gases. In a situation, where an ever increasing specialization makes it more and more difficult to see beyond the boundaries of one's own subfield, such a new field that spans a bridge between different areas of physics, is clearly extremely valuable.

The present book provides an overview of the present status of this field from the ultracold atoms perspective. It covers a broad range of topics, including some of the most recent experimental results as well as novel field-theoretic or numerical methods developed in this context or the issue of a minimum viscosity to entropy ratio that is deduced from the scaling flows of expanding atomic clouds. Special efforts have been taken to make the individual chapters of the book self-contained and accessible to non-experts in the field. It should be stressed that despite a lot of progress over the last few years, many problems are still open, in particular the issue of imbalanced Fermi gases and possible unconventional superfluid phases as well as dynamical properties both near and far from equilibrium. Hopefully, the contributions to this book will provide a valuable introduction not only to the present state of knowledge but also to the still open problems, perhaps providing motivation to address some of the many challenges which remain.

It is a pleasure to thank Wolfram Weise for the initiative to edit a book on this subject within the Lecture Notes in Physics series. My special thanks and appreciation go to all the authors, who have taken off time from research, teaching and many other obligations to write a chapter for this book which provides a self-contained and up-to-date account of their original contributions to the subject. I think they have all done an excellent job.

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