Preface

As we approach the Golden Anniversary of the publication of the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity, appreciation for its conceptual fertility and ubiquity as a paradigm for the behavior of quantum matter has never been greater. The last few years have seen remarkable progress in our understanding of fermionic pairing across an impressive range of physical systems. Beyond the familiar examples of electronic systems in condensed-matter physics, these include ultra-cold atomic vapors, superfluid ^{3}He, finite nuclei, nucleonic matter, and quark matter. One common feature that has emerged is a tension between factors that favor standard Cooper pairing (simple attractive forces between the fermions) and factors that disfavor it (typically, conservation laws that separate the Fermi momenta of different species). Other complications arise from the state dependence and momentum-space structure of the realistic fermion-fermion interactions, medium-modification of these interactions and of consistent fermion self-energies, and retardation effects due to finite propagation times of exchange bosons. To understand the implications of such conflicts and complications, we need to extend the standard Bardeen-Cooper-Schrieffer (BCS) theory to cover a much wider class of possible fermionic pairing patterns.

The topic of non-conventional fermion pairing is particularly rich in opportunities for interdisciplinary cross-fertilization, because it draws together theoretical ideas from atomic physics, condensed-matter physics, nuclear physics, particle physics, and astrophysics. These ideas have direct relevance to experiment. Pairing in cold, high-density quark matter will drastically affect the transport properties underlying the astrophysical signatures that are sought by astronomers studying neutron stars. Pairing in isospin-asymmetric nuclear systems is an important facet of the physics of nuclei far from stability being created at radioactive ion-beam facilities and in natural stellar nucleosynthesis, as well as the physics of neutron-star interiors. Experimental studies of ultra-cold, trapped atomic gases continue to energize one of the most successful and fast-growing areas of mainstream physics, at the crossroads of new thrusts in condensed-matter physics, atomic physics, quantum optics, and quantum-information science.

This book collects a coherent set of expositions on fermionic pairing that grew out of lectures given in the Institute for Nuclear Theory at the University of

Washington. The chapters cover theoretical aspects of fermion pairing in various areas of intense current research.

In assembling the volume, it has been our intent to provide an accessible and useful introduction to basic principles of the theory of superfluid systems, and to their specialized application in a number of physical contexts. This aim is reflected in the arrangement of the chapters, which divide naturally into three blocks. The first block, comprising Chapters 1-5, examines fermionic pairing at the *subnuclear* level through explorations of color-superconducting phases of deconfined quarks at high baryon densities. The second block (Chapters 5-8) is devoted to pairing at the *nuclear* level, focusing on the formation of pair-condensed nucleonic superfluids below the deconfinment density in neutron-star matter and nuclear matter; some attention is given also to the higher-order clustering phenomenon of quartetting in both infinite nuclear matter and finite nuclei. The third block (Chapters 9 & 10) is concerned with pairing at the *atomic* level, as exemplified in dilute, ultracold systems of trapped fermionic atoms; at the same time, it addresses important theoretical issues of wider interest that arise when the pairing is between two fermionic species with unequal densities. Each block starts with an opening chapter which gives a broader perspective of the corresponding topical area.

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