Calogero–Sutherland models describing particles that interact via long-range exchange interactions. These models, not as heavily studied as the Heisenberg or Hubbard model, are fascinating in their own right and require significant generalizations of the standard methods. The book provides a welcome introduction presented with verve and clarity.

My only regret and criticism is that too much is left out of this slim monograph. But perhaps the omissions reflect the author's intent to make *Beautiful Models* accessible rather than exhaustive.

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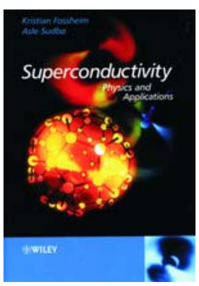
Superconductivity: Physics and Applications

Kristian Fossheim and Asle Sudbø
Wiley, Hoboken, NJ, 2004. $110.00 (427 pp.). ISBN 0-470-84452-3

Kristian Fossheim and Asle Sudbø's *Superconductivity: Physics and Applications* is a modern review of the subject. The book covers key aspects of superconductivity, outlined in a clear and logically structured form. It also provides much up-to-date information and covers advanced topics. This work is one of the first general monographs about superconductivity written after the discovery of high-temperature superconductors (HTSs), an event that has led to considerable new kinds of investigations.



The book discusses many novel classes of superconductors: oxide, organic, heavy-fermion, and magnesium diboride. Except for MgB_2, the classes, for the most part, were found before HTSs but were typically regarded as exotic materials, and their features were not described in other monographs. Maybe the only new, interesting class is magnetic superconductors, which are not mentioned in the book. The coexistence of superconductivity and magnetism currently attracts much interest among researchers. Inclusion of the subject would have been useful in completing the story of a modern view of superconductivity.

The theory of superconductivity, even in its simplest description, still needs to be updated, especially in light of new superconducting materials. The authors discuss superconducting order-parameter symmetry, anisotropy, and the quasi-two-dimensionality of electron and vortex systems as necessary elements of a modern theory of superconductivity. Investigations of HTSs have led to many exciting developments in vortex structures, pinning, and dynamics—and such meaty topics richly deserve their place in the book. The authors have written readable and accurate sections on such new topics as thermally activated creep and collective creep, geometric barriers, and solid–liquid transition in vortex structures. However, they could have expanded discussions on fluctuations in low-dimensional superconductors: Only the Kosterlitz–Thouless transition and vortex–antivortex unbinding and disordering by other topological defects are discussed in detail. On the other hand, a full-length review of the superconducting–normal (SN) transition problem is very useful, even if the discussion is of interest to only a small group of readers.

Fossheim and Sudbø devote insufficient attention to Josephson structures. They only briefly mention novel effects like plasma oscillations in multilayered superconducting systems, and leave out such important subjects as macroscopic quantum phenomena in submicron-scale Josephson structures. A discussion of those new directions in superconductivity could have been placed in sections on "Advanced Topics" or "Topical Contributions."

Fossheim and Sudbø's choice of subjects and contributing authors for the topical contributions is random, and presented papers are fragmentary. For example, Yoshiteru Maeno's paper covers spin-triplet superconductivity but does not mention recent publications by Kostya Efetov and colleagues, which are related to possible spin-triplet superconductivity in multilayered superconductor–ferromagnet structures. Jochen Mannhart's paper describes π-junctions based on d-wave symmetry in HTS systems but fails to mention π-junction realizations in superconductor–ferromagnet–superconductor Josephson junctions and mesoscopic SN structures.

In "Selected Applications," the authors also create a general impression that the book is incomplete. For instance, they do not mention that Josephson-junction applications also include rapid single-flux quantum Josephson logic, microwave flux-flow generators and receivers, amplifiers based on superconducting quantum interference devices, and so forth. In their discussion of high-frequency applications of superconductors, the authors also should have mentioned superconducting bolometers and switches.

Although the second half of *Superconductivity* is somewhat disconnected, the monograph as a whole offers a fresh look at the modern state of superconductivity. Certainly, it is not a book for readers who are new to superconductivity, but for scientists familiar with and interested in superconductivity, the new monograph has many interesting moments.

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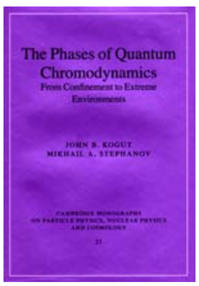
The Phases of Quantum Chromodynamics: From Confinement to Extreme Environments

John B. Kogut and
Mikhail A. Stephanov
Cambridge U. Press, New York, 2004. $110.00 (364 pp.). ISBN 0-521-80450-7

In recent years, physicists have realized that there are more phase transitions in quantum chromodynamics (QCD) than just the one that separates the world of hadrons from the quark–gluon plasma, where color charges become deconfined and chiral symmetry is restored. Particularly in the domain of low temperatures and high baryon densities, researchers have found a good number of phases that are strikingly similar to systems from condensed matter physics such as electronic superconductors or superfluid helium-3. Those QCD phases can be studied systematically at low temperatures and asymptotically large baryon densities via weak-coupling methods. At high temperatures and moderate baryon densities, considerable progress has been made by extending lattice gauge theory calculations from zero to low, nonzero baryon densities.

Why are the developments mentioned above interesting? QCD is not the only theory of elementary interactions that features various phases, but it is the only one in which the transition between phases can be experimentally investigated. The transitions are studied via heavy-ion collisions and by observing the properties of compact stellar objects. The phase transitions of QCD also have had a profound influence on the evolution of the early universe.

A textbook that gives an overview of and ready access to the fascinating and rapidly evolving field of QCD under extreme conditions is long overdue. John Kogut and Mikhail Stephanov's *The Phases of Quantum Chromodynamics: From Confinement to Extreme Environments* is a much-anticipated book. Kogut is eminent in lattice QCD and has made seminal contributions to the field, and to high-energy and condensed matter physics in general. Stephanov is a leader in the study of QCD under extreme conditions and has made important contributions to the interpretation of lattice-QCD results at nonzero baryon densities, the experimental observability of the critical point, and collective excitations in color-superconducting quark matter.



To learn about the phases of QCD, one has to realize that almost everything of current theoretical and experimental interest happens in a regime where the QCD coupling constant is large—that is, where hadrons compete with quarks and gluons for the ground state at a given temperature and baryochemical potential. The large coupling, in turn, prevents the use of perturbative tools. A first-principles approach that gives reliable and rigorous results in the nonperturbative region is lattice QCD. Consequently, Kogut and Stephanov first give a pedagogical and highly illuminating introduction to lattice gauge theory, starting with spin systems and working their way successively toward lattice QCD by first generalizing spins to gauge fields and then introducing fermions on the lattice. I found their particular approach very useful, especially for particle physicists who are not practitioners of lattice QCD and who want to get a good overview of the basic concepts and methods that are used by their colleagues. However, the book contains much more than just the basics. The authors also present such highly specialized topics as instantons and topology in gauge theories, in a very appealing, pedagogical way.

The authors then tour the phase diagram of QCD and discuss how the basic features can be gleaned from symmetry considerations and simple phenomenological facts. The line of argument is elegantly presented and should be appealing and useful to students who want to enter the field and learn the basics of the QCD phase diagram. Kogut and Stephanov's discussions also impressively demonstrate how much one can learn from symmetry alone. Their tour ends at asymptotically high temperatures and densities where QCD is a weakly coupled theory. Consequently, perturbation should be applicable to describe that region of the QCD phase diagram. But about 20 years ago, researchers realized that this is not quite true at sufficiently low temperatures because quarks form Cooper pairs and give rise to color superconductivity. Cooper-pair condensation is an intrinsically nonperturbative phenomenon because the energy gap is a nonanalytic function of the coupling constant. Depending on the particular quantum numbers of the pair, a multitude of different color-superconducting phases of quark matter are possible.

Kogut and Stephanov do a very good job explaining the basic concepts of color superconductivity and exploring the properties of the so-called color flavor-locked phase, which is the ground state of three-flavor quark matter at asymptotically large baryon densities. As this is a rapidly evolving field, the presentation in the book is not at the most recent level, but the authors are aware of that and certainly cannot be held responsible.

So where do physicists stand? Lattice-QCD calculations employ methods that work well at any temperature and at vanishing baryochemical potential. On the other hand, weak-coupling methods work well at asymptotically high temperatures and baryochemical potentials. The interesting region of zero to intermediate temperatures and nonzero baryochemical potentials is currently beyond the reach of theoretical tools. The reason for such a predicament is that a difficulty called the fermion-sign problem prevents researchers from applying first-principles lattice-QCD methods in that region, and the authors spend the last chapters of their book elaborating the point. They present simple models that could lead to progress in solving the sign problem. The models are either analytically under control even at nonzero baryochemical potential or, in principle, amenable to the lattice approach. Kogut and Stephanov also discuss several recent, promising attempts to perform lattice-QCD calculations at small, nonzero baryochemical potentials.

The Phases of Quantum Chromodynamics gives a well-structured overview of the phases of QCD under extreme conditions. Of course, not everything in this rapidly evolving science can or should be presented in a textbook, but the selection by the authors is informative and represents the activities in the field quite well. My main criticism is that the references are sparse. The reader is often told that more details can be found in the literature, but no reference is provided. Also, the discussion is not really on an elementary level. Although the authors do a good job keeping the discussion as simple and pedagogical as possible, students without some knowledge of statistical field theory may have a hard time understanding some of the material. Nevertheless, for scientists working in the field, the book is a must. And for those who want to learn more about the fascinating world of QCD under extreme conditions, it is a very good starting point.

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New Books

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