Elementary excitations in quantum fluids

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Elementary Excitations in Quantum Fluids. Eds. K. Ohbayashi and M. Watabe. Springer-Verlag, Berlin; Heidelberg; New York, London; Paris; Tokyo, 1989. 197 p. (Springer Series in Solid-State Sciences, Vol. 79).

The book under review is a collection of reports given at a conference on elementary excitations in quantum fluids that took place in Hiroshima in August of 1987.

The description of weakly excited states of macroscopic bodies in terms of elementary excitations–quasiparticles–is fundamental to solid state physics. This theory of elementary excitations turns out to have much in common with elementary particle theory. This similarity is far from accidental, of course. After all, elementary particles can be considered to be excitations of a specific medium—the vacuum. In this sense elementary particle theory is a particular case of the theory of elementary excitations. It is hardly surprising, therefore, that the technical apparatus of both theories is essentially identical.

Nonetheless, in some ways the theory of elementary excitations is richer. First of all, in the theory of elementary excitations one encounters a wide variety of different media, instead of vacuum alone. But even more importantly, relativistic invariance causes the dependence of energy on momentum to be the same function of particle mass for all elementary particles, whereas the dispersion of elementary excitations remains a fundamental object of research.

The simplest and possibly most important type of medium in the physics of elementary excitations is an isotropic quantum liquid–liquid helium isotopes and their mixtures. The collection under review is devoted to new results on excitations in these media.

A general review of the current state of macroscopic Bose-liquid theory is given by K. Campbell and B. Clements. This review demonstrates that modern numerical techniques have enabled us to interpret quantitatively most of the observed properties of ^{4}He.

Currently, Raman scattering and inelastic neutron scattering are the two dominant methods of investigating elementary excitations. These methods are both covered in the book.

Notable in this regard are the rather successful presentation of the theory of Raman scattering in ^{4}He by J. Kelly and the review of experimental results by K. Ohbayashi. The interpretation of polarization effects in scattering is of great current interest, since these yield information on the structure of the interaction operator between the quantum liquid and the electric field. The paper by J. Ruvalds discussed the weakly bound two-roton state. This object plays the same role in the theory of elementary excitations as the deuteron in elementary particle theory.

A number of reports is devoted to the study of threshold phenomena related to the specific form of the roton spectrum. (Such threshold phenomena are caused precisely by the presence of a medium, i.e., due to the lack of relativistic invariance.) In particular, K. Nagai successfully explains the experimentally measured spectral behavior near the roton decay threshold, while K. Fukushima and F. Izeki succeeded in evaluating the roton-maxon interaction parameters. A number of new threshold effects is predicted by F. Iwamoto.

Much attention is devoted to the temperature dependence of the ^{4}He form factor. This problem is still not fully understood.

On the basis of certain assumptions, S. Sasaki makes an interesting prediction of an additional branch of elementary excitations—the "elementary phonon" branch. The velocity of these excitations should go to zero at the transition point. (It is unclear, however, whether these excitations differ from the usual second sound).

A new experimental technique for studying elementary excitations involves the simultaneous measurement of atomic evaporation from the surface and excitation time of flight (A. Watt).

A number of puzzling phenomena arise from ion motion in ^{4}He. For example, recent measurements (K. Williams and co-workers) confirm the existence of two classes of ions—"fast" and "slow." W. Vinen discusses the possibility of employing ions captured by the surface to study the properties of capillary waves.

This short list should make it clear that the collection under review is nothing less than a real compendium of current research into elementary excitations in liquid helium. One can only envy Springer-Verlag for their ability to ring out this excellently edited volume so quickly after the end of the conference.

This book is part of the Springer Series in Solid State Science, which is characterized by the excellence of its authors and judicious selection of topics.

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