Comment on "Disappearance of Roton Propagation in Superfluid ^{4}He at T_λ"

In a recent Letter on rotons in superfluid ^{4}He, Svensson, Montfrooij, and de Schepper [1] have proposed that the "superfluid transition is marked by a complete softening of the roton mode" in which the roton energy goes to zero at the superfluid to normal transition temperature T_λ. They also note that their data "implies a qualitative disagreement with the interpretation (of excitations in liquid ^{4}He) by Glyde and Griffin" [2]. Since previous neutron scattering measurements have not reported a roton energy that goes to zero as T is increased to T_λ, we believe that these conclusions in Ref. [1] need clarification. In this Comment we make three points.

First, the conclusion in Ref. [1] that the roton energy vanishes at T_λ is not based on new data that disagree with previous data. Rather, it is based entirely on the way in which the data are analyzed. The new measurements of the dynamic structure factor $S(q,\nu)$ in liquid ^{4}He at $p \sim 20$ bars presented in Ref. [1] are in fact entirely consistent with earlier high-pressure data.

Second, at the roton wave vector q_r and at temperatures near T_λ, $S(q,\nu)$ is a very broad function of frequency ν, and there is no physical reason to expect it to arise from a single mode having a constant energy that can be unambiguously defined [3,4]. Svensson *et al.* [1] have made a particular choice for this energy in their analysis and we do not think this choice has any compelling physical significance. Specifically, Svensson *et al.* [1] analyze their data using the single-mode susceptibility $\chi_1(q,\nu)$ [Eq. (2) in [1]], which has been used in most work on ^{4}He for the last 20 years. It can be formally derived [4] from the exact Green function assuming constant (frequency-independent) energies, $f_S^2(q) = \nu_S^2(q) + \Gamma_S^2(q)$, which is valid for small half-widths $\Gamma_S(q)$. Svensson *et al.* [1] obtain it within the Mori formalism. They select ν_S as the mode energy. Their analysis differs from previous work by fitting $\chi_1(q,\nu)$ to the total $S(q,\nu)$, which includes multiexcitations. However, if the multiexcitations components are subtracted off, $\nu_S(q_r)$ does not vanish at T_λ (Refs. [6], [9], and [11] in [1]). If the method used in Ref. [1] is applied to data at $p = 0$, $\nu_S(q_r)$ goes to zero at a temperature *above* T_λ (Ref. [6] in [1]). The essential point is that for $T > 1.85$ K, $S(q,\nu)$ is broad and the frequency dependence of $\nu_S(q,\nu)$ is important. If a constant mode energy ν_S is selected, then its value depends on how it is defined and on how the multiexcitations are treated (see Refs. [6] and [11] in [1]). Also, the temperature at which $\nu_S \to 0$ depends on pressure. It is therefore difficult to attribute any physical meaning to the softening at $p = 20$ bars of ν_S at T_λ reported in Ref. [1].

Third, Glyde and Griffin [2] did not, as stated in Ref. [1], propose the appearance of "a renormalized single-particle mode replacing the regular density fluctuations of normal fluids as one goes below T_λ." Rather, Glyde and Griffin noted that when a Bose fluid has a condensate there are two contributions to $S(q,\nu)$. One is the regular density response involving finite momentum states ($k \neq 0$ states) common to all fluids and the other arises from exciting single particles out of the condensate (the $k = 0$ state). As T is reduced below T_λ, the condensate fraction $n_0(T)$ grows and the second component gradually begins to contribute to $S(q,\nu)$. In a strongly interacting Bose fluid such as liquid ^{4}He, the two contributions are strongly hybridized, giving rise to a single sharp peak in superfluid ^{4}He at the roton wave vector. Over a large temperature range, $S(q,\nu)$ is very different above and below T_λ, the position of the sharp peak below T_λ can differ from the position of the broad maximum in $S(q,\nu)$ above T_λ, and these differences are attributed to the single quasiparticle contributing to $S(q,\nu)$ below T_λ. Since the new data of Svensson *et al.* [1] are the same as previous data, it does not cast new light on the interpretation by Glyde and Griffin [2].

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