Comment on "Zero Sound Mode in Normal Liquid ^{3}He"

In a recent Letter [1] Albergamo *et al.* present high accuracy inelastic x-ray scattering results on normal fluid ^{3}He. Their data extend the region of accessible momentum transfers beyond previous [2] neutron scattering experiments. The authors convincingly show that a damped harmonic oscillator (DHO) model yields an excellent description of the data. Based upon their fitted DHO parameters, the authors conclude that the anticipated effect [2] of strong damping of the collective zero sound mode (ZSM) when it interacts with the particle-hole continuum does not materialize. We argue that the opposite cannot be ruled out.

Clearly, the DHO gives a very good description [1] of the x-ray data; however, we believe that the parameter $\Omega(Q)$ is not the right choice to uncover the presence of a strong damping mechanism. Using the author's DHO model and notation, Ω is given by the ratio of two frequency moments [3]

$$\Omega(Q)^2 = \frac{\int \omega S(Q,\omega)d\omega}{\int \omega^{-1} S(Q,\omega)d\omega}. \quad (1)$$

This ratio is insensitive to changes in propagation frequency f, even in the presence of strong damping. The situation is equivalent to a mass m hanging from a spring with spring constant k. While f depends on whether the spring is suspended in air or in water, $\sqrt{k/m}$ (the equivalent of Ω) is the same in both instances. Thus, $\sqrt{k/m}$ (Ω) is not suited to scrutinizing the decay mechanisms in water (particle-hole continuum).

A more sensitive measure is given by the poles of the dynamic susceptibility $\chi(Q,\omega)$, which are located at $z = i\Gamma \pm \sqrt{\Omega^2 - \Gamma^2}$ in the complex plane. When the damping Γ becomes important the excitations will soften and become overdamped once $\Gamma > \Omega$. The importance of using the poles of $\chi(Q,\omega)$ in the description of quantum liquids was illustrated in pressurized ^{4}He (density = 26 atoms/nm^3) close to the superfluid transition [4]: while excitations could be seen to change from undamped to overdamped with increased temperature, Ω barely showed any change over the same range.

In Fig. 1 we replot the authors' fit parameters [1] as $\omega_{ZSM} = \mathrm{Re}[z]$. It is clear that the ZSM softens to the point of becoming overdamped when it enters the particle-hole continuum; the excitations are damped out in less than 1/4 of a cycle, the opposite of a well-defined mode. Since this is exactly the type of behavior one would expect in case of a strong interaction between the ZSM and the particle-hole continuum, we conclude that the authors' main conclusion [1] is premature. We also note that our analysis has brought the neutron and x-ray scattering data into good agreement.

The final verdict should come from a detailed comparison with the behavior of normal fluids [5]. Considerable softening of the ZSM is frequently encountered in normal fluids; however, we are not aware of such strong softening ever having been observed in a fluid at low density (density ^{3}He = 16 atoms/nm^3). For these low densities one normally finds [5] that $\Gamma < \Omega$. Thus, it appears that the particle-hole continuum does provide an extra decay channel for the ZSM in ^{3}He.

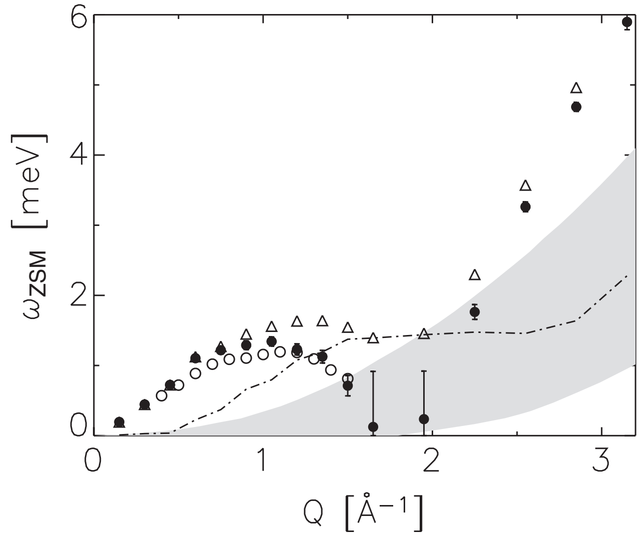

FIG. 1. The propagation frequency ω_{ZSM} of the zero sound mode in ^{3}He (x-ray [1]: filled circles; neutron [2]: open circles). In the region of the particle-hole continuum (shaded area) the damping Γ (dashed line) becomes comparable to Ω (triangles) and the ZSM undergoes considerable softening. The error bars are based on the size of the symbols in Fig. 3 in Ref. [1].

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Received 22 November 2007; revised manuscript received 28 January 2008; published 10 June 2008
DOI: 10.1103/PhysRevLett.100.239601
PACS numbers: 67.30.em, 61.05.cf

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