# $\rho_s$ of Confined $^3$He-$^4$He Using Adiabatic Fountain Resonance

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**Abstract**

We have previously described a resonance involving the adiabatic motion of $^4$He from a superleak into a reservoir. We consider here the case of $^3$He-$^4$He mixtures and show some preliminary results for $\rho_s$ for confinement in a film geometry at $L = 0.0483\mu m$. We relate this to the behavior expected from correletion-length scaling.

*Keywords:* confined helium; mixtures; scaling; adiabatic fountain resonance

Confined $^4$He near $T_\lambda$ should be scaled by functions which involve only bulk critical exponents.[1] Some experiments have been done to address this scaling.[2] For mixtures there are not as much data to address these issues.[3] The expectation is that the same scaling as with the pure system should apply only with a different amplitude, $\xi_0$, for the correlation length. We have reported previously results for the superfluid density, $\rho_s$, obtained using Adiabatic Fountain Resonance (AFR).[4] We extend this technique now to mixtures.

The experimental cell which we use consists of two wafers of silicon bonded at a uniform separation of 0.0483 $\mu$m. This provides a planar confinement for the helium. The cell acts as a superleak. Thus, one can excite a resonance in which the superfluid oscillates from the cell into the filling line. The resonance is accompanied with pressure and temperature oscillations at the cell, and height oscillations in the filling line. The resonance is analogous to a Helmholtz resonance, but with the superleak connected to only one chamber. The resonance frequency is not defined by a standing wave condition, but rather by the geometry of the flow, the superfluid fraction and the compressibility. For pure $^4$He, an adiabatic resonance between two reservoirs connected by a superleak was first considered by Robinson.[5] More recent analyses have also been done.[6] We have described an analysis of AFR for $^4$He and the particular geometry of our experiment.[4] In the present case, for mixtures, flow of the superfluid is driven by differences in temperature, pressure and, as well, in the relative chemical potential, $\phi = \mu_3 - \mu_4$. An additional equation describes the heat conduction. The resonance frequency from these equations is given by

$$\omega_R = \omega_0 \sqrt{1 + \alpha(T,x) - \beta(T,x)} \qquad (1)$$

where the terms $\alpha$ and $\beta$ are thermodynamic parameters which are functions of temperature and $^3$He concentration, $x$. They are typically less than 0.1. $\beta$ is a new term; it vanishes when $x = 0$. The frequency $\omega_0$ is given in [4] and contains $\rho_s$.

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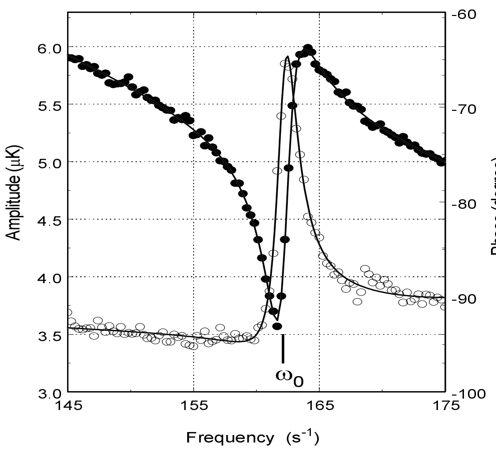


Fig. 1. Amplitude, •, and phase, ○, at $t = 0.04$. Solid lines are fit to data using Eqs. which appear in Ref. 4

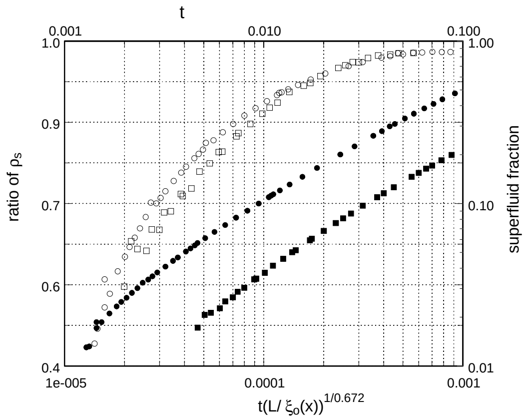


Fig. 2. Superfluid fraction,filled symbols, as function of $t$; and, scaling plot of the same data, open symbols. Boxes, are for $^4$He, and circles are for $x = 0.36$.

To make contact with experiment one relates the magnitude of the temperature oscillations, which we measure, to the frequency at the heater; and, the phase shift of this signal relative to the heater drive. These eqs. are given in [4]. Here they apply to the mixtures, but with different parameters. An example of these signals and the fit to them is shown in Fig.1. Both the phase and amplitude are fitted well. $\omega_0$ is obtained independently from either the phase or the amplitude. For Fig. 1 $\omega_0 = 162.09 \pm 0.02 Hz$. Note that $\omega_0$ is not at any obvious feature of these curves; but, it is close to the maximum in the phase.

From such fits one obtains the superfluid fraction. This is shown in Fig. 2 for pure $^4$He, and $x = 0.36$, solid symbols, as a function of $t = (1 - T/T_\lambda)$. The data do not approach the transition very closely because the resonance is strongly damped for small $t$. Scaling predicts that the ratio of the confined to the bulk superfluid fraction should be a universal function of $t(L/\xi_0)^{1/\nu}$. This plot is also shown in Fig. 2, open symbols. One can see that the data tend to scale, but not perfectly. Specifically, for the mixtures a value of L somewhat smaller than the geometrical L would collapse the data better. This is quite reasonable. The preference of $^4$He for the solid surface effectively limits the spacial extent to which one has a uniform mixture.

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