

# Acoustic Spectroscopy of Superfluid $^3\text{He}$ in Aerogel

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**Abstract:** We have designed an experiment to study the role of global anisotropic quasiparticle scattering on the dirty aerogel superfluid  $^3\text{He}$  system. We observe significant regions of two stable phases at temperatures below the superfluid transition at a pressure of 25 bar for a 98% aerogel.

**Keywords:** Superfluidity, Helium 3, Aerogel

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## INTRODUCTION

Ultrasonic spectroscopy has proven to be a powerful tool in the study of  $^3\text{He}$ . The acoustic impedance for transverse sound exhibits anomalies at phase transitions that mark the superfluid phase diagram of  $^3\text{He}$  in 98% porosity silica aerogel [1]. The scattering of  $^3\text{He}$  quasiparticles from the silica aerogel strands suppresses  $T_c$  and stabilizes the  $B$ -phase. An  $A$ -like phase is found to be metastable in zero field with large supercooling [1]. This is consistent with NMR [2] and low-frequency sound velocity measurements [3].

More recent acoustic tracking experiments by Vicente *et al.* [4] and NMR by Osheroff *et al.* [5] (99.3% aerogel) reveal that the  $A$ -like phase is in fact stable in a small temperature window near  $T_c$  at high pressure. Vicente *et al.* suggest that this stabilization is due to the *local* anisotropic scattering from the aerogel strands. Furthermore, they propose introducing *global* anisotropy by uniaxial compression of the aerogel to study the effect.

## THEORY

Sauls [6] and Thuneberg *et al.* [7] have shown that local anisotropy can stabilize the axial state of superfluid  $^3\text{He}$  within aerogel. The relative stability of the axial ( $A$ ) and isotropic ( $B$ ) phases can be expressed as the difference between the beta parameters. The beta parameters are the coefficients of the fourth order terms in the Ginzburg-Landau expansion of the free energy in powers of the order parameter and are proportional to the difference in the heat capacity

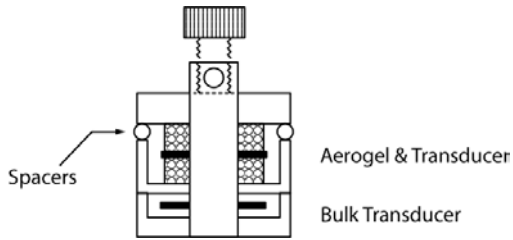
jumps. Sauls also noted [6] that large length scale correlations, or global anisotropy, in the aerogel might also favor phases with the orbital wavefunction perpendicular to the anisotropy axis, namely the planar or axial phases.

## EXPERIMENT

In order to study the role of anisotropy, one needs a probe that is both directional and extremely sensitive to phase transitions in the  $^3\text{He}$ . Transverse acoustic impedance has been shown to give a clear signature of all phase transitions in  $^3\text{He}$  [1]. The magnetic field dependence of the phase diagram allows us to assign which phases are equal spin pairing (ESP), like the  $A$ -phase or non-ESP, like the  $B$ -phase.

We designed and built a cell to compress a pair of aerogel samples that sandwich an *ac*-cut quartz acoustic transducer, as shown in Fig. 1. The electrical impedance was measured with a continuous wave impedance bridge [8]. A melting curve thermometer (MCT) was used as the primary thermometer.

The 98.2% aerogel in this experiment was grown at Northwestern using a two-step synthesis with rapid supercritical extraction (RSCE); and  $\sim 10\%$  shrinkage was observed. Similar aerogels were studied by small-angle x-ray scattering (SAXS) as a function of compression [9]. Anisotropy increases systematically with uniaxial compression. Additionally, there is evidence of some intrinsic anisotropy [9].



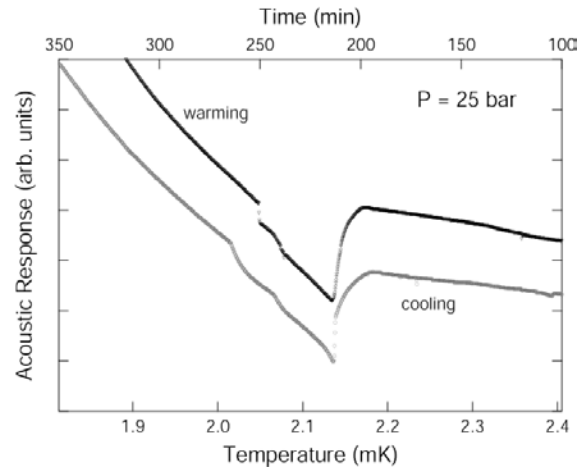
**FIGURE 1.** Compression cell. Spacers ensure transducer contact to the nominally uncompressed aerogel.

In our preliminary work, we performed temperature sweeps, Fig. 2, to determine how the  $^3\text{He}$  might be affected by this aerogel before removing the spacers and compressing the samples; this is the data that we present here.

## DATA AND RESULTS

At a pressure of 25 bar the bulk transition is at 2.36 mK, and is indicated by a separate bulk-transducer, Fig. 1. This trace is not shown in Fig. 2. We see no evidence for a bulk transition with the aerogel-sample transducer. In addition, the superfluid transition temperature in aerogel is less suppressed than previously observed by Gervias for a comparable porosity aerogel [1] ( $T_{ca} = 1.91$  mK). The transition from normal to superfluid appears to be in two parts, the superposition of a broad transition and a narrow transition. At lower temperatures there are also two distinct features in the acoustic impedance. On warming one of these is exceedingly sharp ( $\Delta T \approx 2$   $\mu\text{K}$ ) and it exhibits a small hysteresis that can be associated with a first order transition. All of these features have been reproduced on multiple temperature sweeps.

The double transitions can most naturally be associated with there being two, non-identical, aerogel samples with which the transducer is in contact. Tentatively we associate the two low temperature features as transitions from  $B$  to  $A$ -like phases on warming, based on: a) previous studies of transverse impedance experiments [1], and b) their supercooling. The stability of the  $A$ -like phase might be a consequence of intrinsic global anisotropy [9], or possibly anisotropy introduced by nominal strain from the sample holder. Further work at different pressures and as a function of compression and magnetic field should help to clarify this situation.



**FIGURE 2.** Acoustic impedance measurements of phase transitions for  $^3\text{He}$  within a 98.2% aerogel. The major feature is the transition to superfluid in aerogel; smaller features are discussed in the text.

## CONCLUSIONS

Preliminary studies of  $^3\text{He}$  at 25 bar in 98% aerogel grown at Northwestern suggest that an  $A$ -like phase can be stabilized, likely due to global anisotropy induced in the aerogel sample.

## ACKNOWLEDGMENTS

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