Gapless Superfluid ^{3}He in High Porosity Aerogel

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Introduction

Superconductivity or superfluidity is generally associated with the appearance of a gap in the energy spectrum. However, in the presence of disorder or impurity, superfluidity may appear without a clean energy gap: gapless superfluid. This is caused by impurity scattering whose effect is much more pronounced in unconventional pairing superfluid such as superfluid phases of ^{3}He. Our high frequency sound attenuation measurements down to zero temperature limit (200 μK) in the superfluid phase of ^{3}He impregnated in high porosity silica aerogel revealed completely different behavior in comparison with the pure superfluid phases.

Experimental

We have made ultrasound attenuation measurements by direct propagation of 1 μs ultrasound pulses (9.5 MHz) in the B-like phase of superfluid ^{3}He in 98% porosity aerogel. Our measurements were able to reach down to the zero temperature limit (200 μK) using the Bay #2 in the Microkelvin Laboratory. We are currently conducting the same measurements in the A-like phase stabilized by magnetic field.

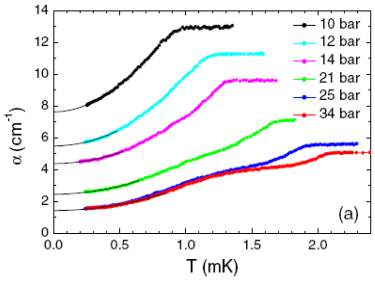

Fig. 1

Results and Discussion

As shown in figure 1, the ultrasound attenuation observed in aerogel presents a drastically different behavior compared to that of the bulk liquid. There are no features (attenuation peak) associated with the pair-breaking mechanism and the coupling to the order parameter collective modes. The temperature dependence is not exponential as expected in the pure B phase and the attenuation remains fairly high down to $0.2T/T_c$. The normalized zero temperature attenuation increases with decreasing pressure eventually reaching to the normal state value at P ≈ 6.5 bar, where the normal to superfluid quantum phase transition has been suggested (Fig. 2). These observations are consistent with the presence of subgap impurity bound states caused by pair-breaking scattering. Specifically, the zero temperature attenuation α_o is directly related to the density of states at the Fermi energy, $N(0)$, by $\alpha \approx N(0)^m$, $m = 2$ for the Born limit and $m = 4$ for the unitary limit [1,2]. As the sample pressure decreases, the pair-breaking effect becomes stronger leading to gapless superlfuid.

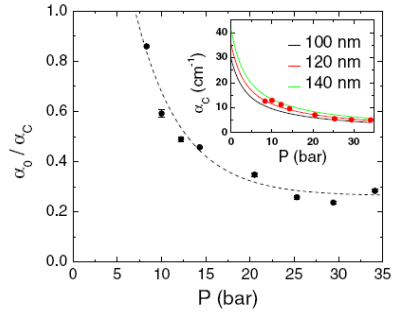

Fig. 2

Conclusions

Our results provide strong experimental evidence of gapless superfluidity in ^{3}He impregnated in 98% porosity aerogel. The presence of impurity bound states inside the gap also extinguished the order parameter collective modes associated with unconventional pairing. This work is published in *Phys. Rev. Lett.* [2].

Acknowledgements

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