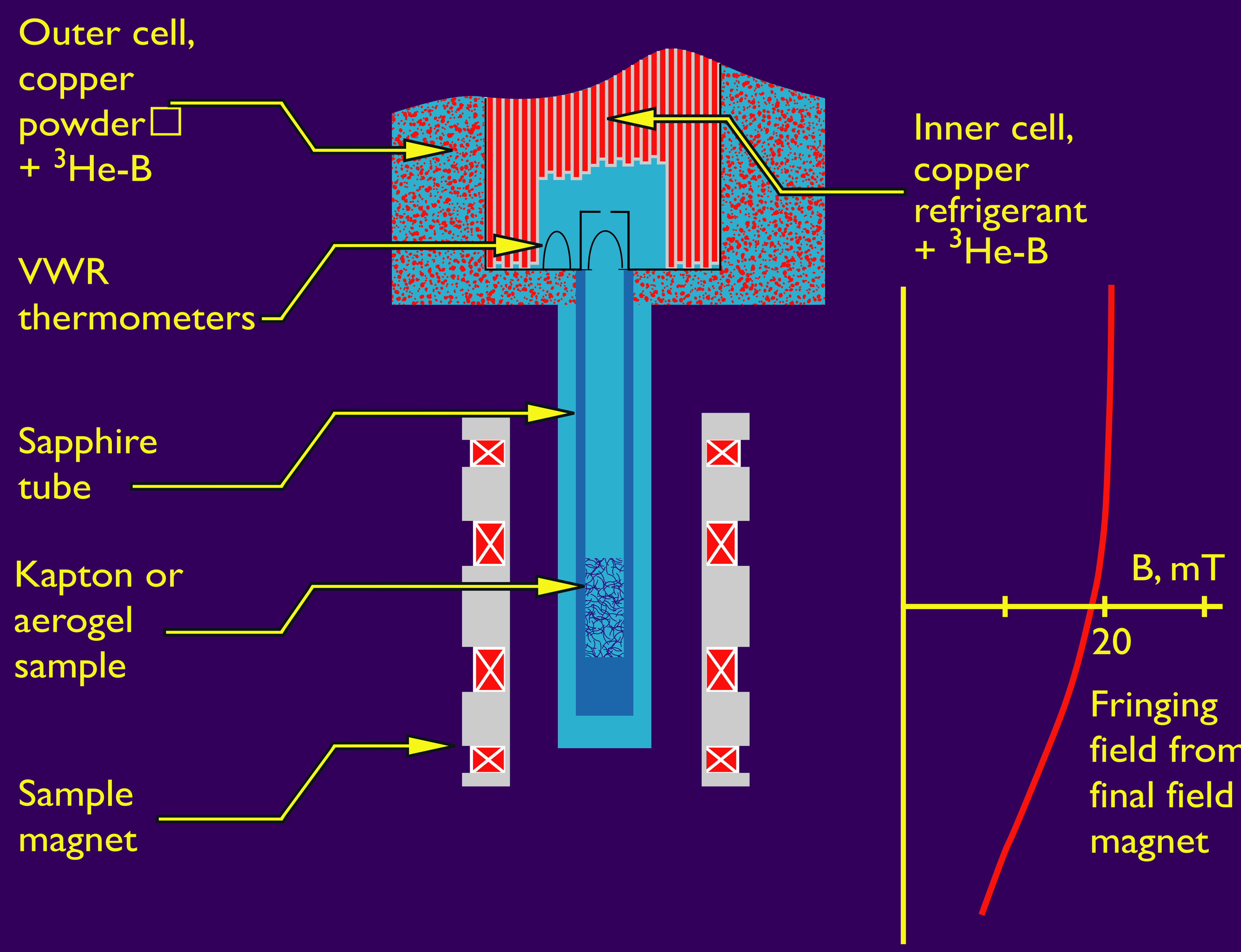
Coupling Between Aerogel and Superfluid ^{3}He in the Low Temperature Limit

D.I. Bradley, S.N. Fisher, A.M. Guénault, R.P. Haley, G.R. Pickett, P. Skyba and R.C.V. Whitehead

LANCASTER UNIVERSITY DEPARTMENT OF PHYSICS

Overview

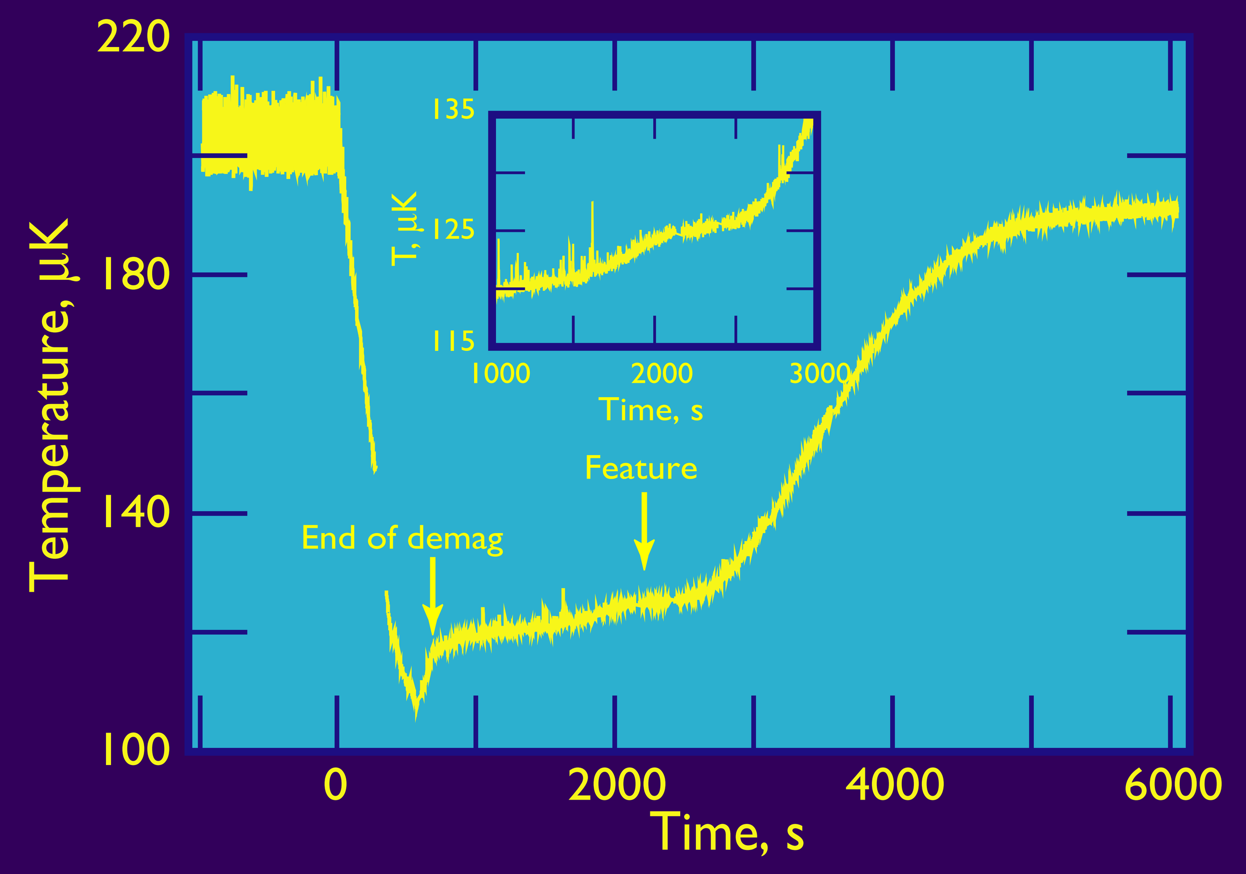
Superfluid ^{3}He-B black-body radiators are extremely sensitive to very small power inputs. During measurements on the superfluid A-B boundary[1], temperature changes were observed whenever the magnetic field changed, even though the radiator contained only B phase. This effect was associated with the Kapton radiator walls and was virtually eliminated when sapphire walls were used. To investigate, we carried out experiments with a sapphire-walled black-body radiator containing a Kapton sample and later a 98% aerogel sample. The effects were similar in both cases. The data shown here is taken from a 3.7 mg aerogel sample (estimated surface area 2.19 m^2).



The main bulk ^{3}He-B sample is cooled to ~120μK in a Lancaster-style cell, with VWRs as heaters and thermometers. The aerogel sample is placed in the black-body radiator at the centre of a superconducting magnet where the ^{3}He only typically cools to ~200μK due to the heat leak from the walls. The magnet field profile is designed to give a low field over the VWRs at the top of the radiator. The demagnetisation final field solenoid produces a field gradient over the sample.

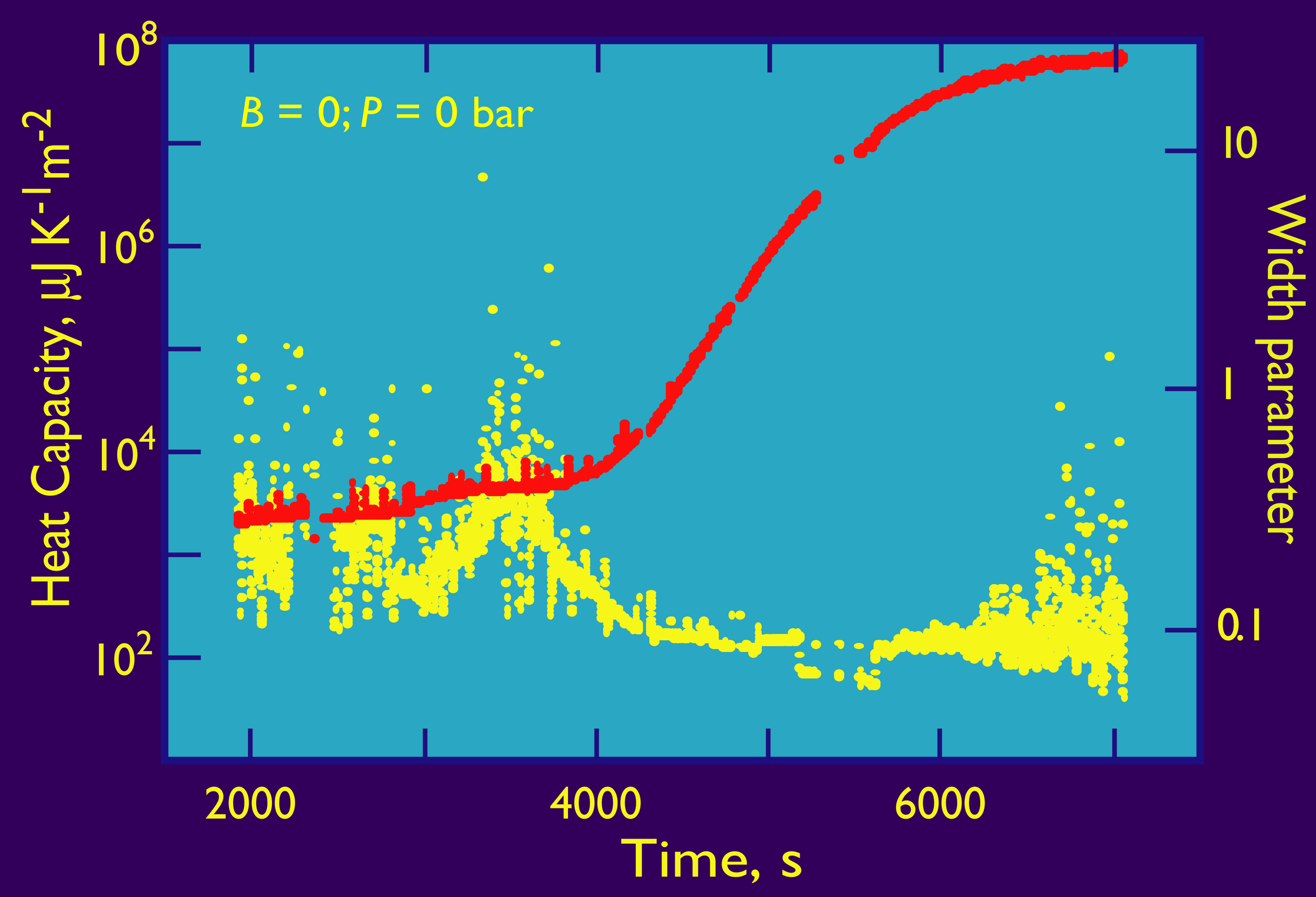
References

1. M. Bartkowiak et al, Phys Rev Lett 85, 4321 (2000)
2. S.N. Fisher et al, Phys Rev Lett 69, 1073 (1992)
3. D.T. Sprague et al, Phys Rev Lett 75, 661 (1995)



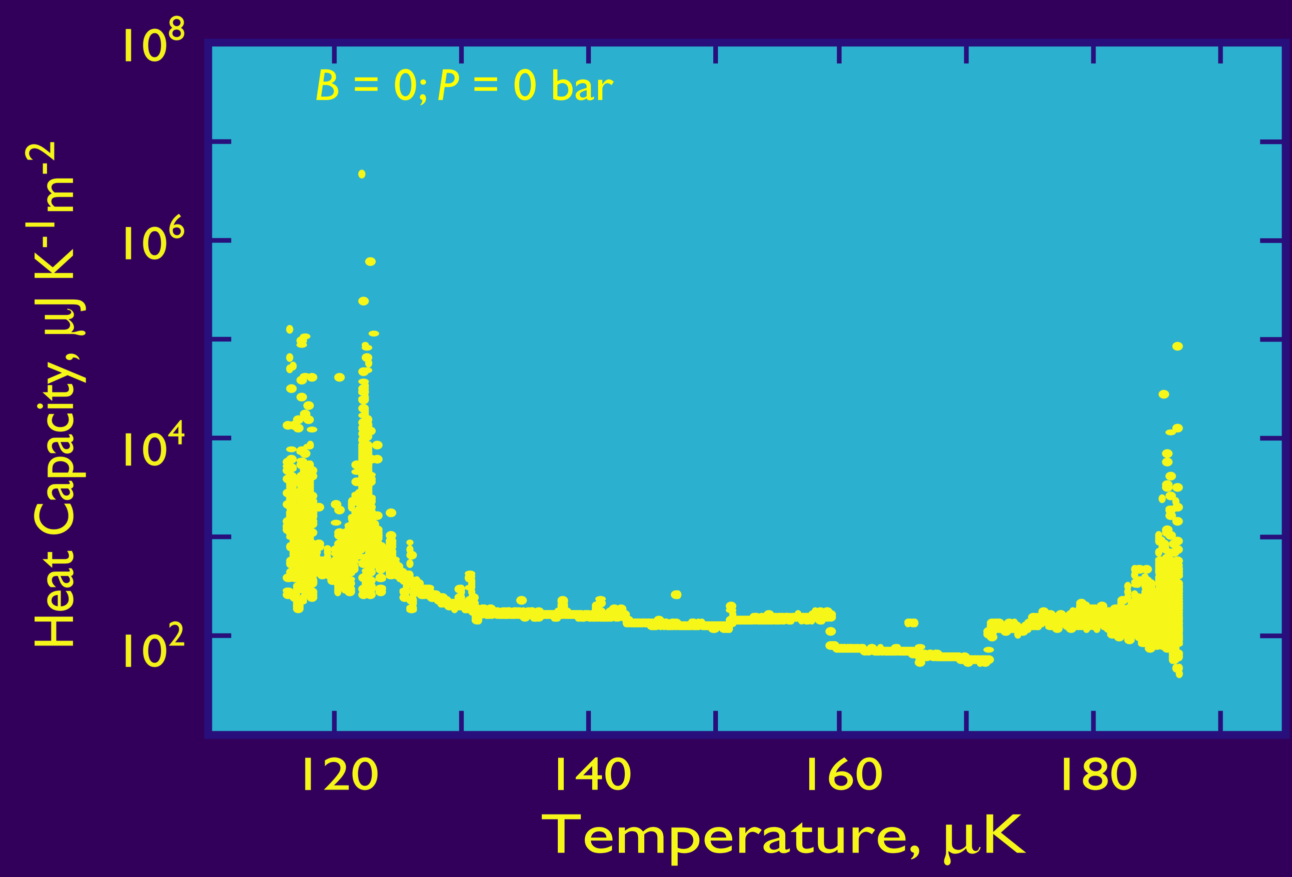
Demagnetisation

On demagnetising the sample we see rapid cooling. The heating during the later stages of the demagnetisation arises from the field gradient over the sample causing the field to increase on some parts of the sample. After demagnetisation, the ^{3}He warms up over a period of several thousand seconds. A small feature (also inset) is observed, possibly indicating an ordered state.

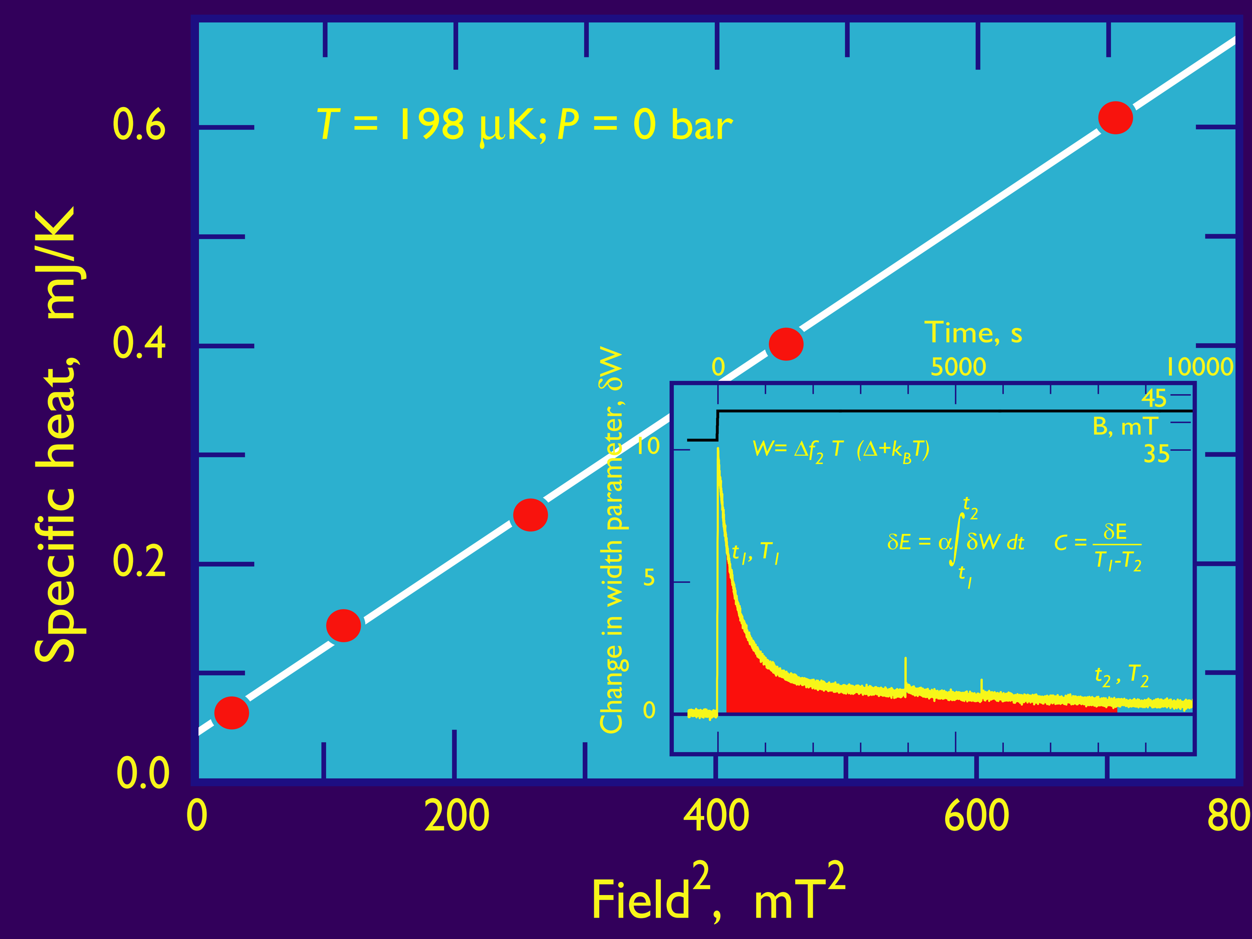


Heat Capacity

Using a simple model we can estimate the heat capacity dQ/dT = dQ/dt · dt/dT, knowing the box calibration and assuming a constant heat leak. Plotting the heat capacity and width parameter as a function of time, it is clear that there is a very large peak in the heat capacity corresponding to the flat region in the width parameter, possibly indicating a phase transition. These measurements are taken in zero total field and at zero bar pressure.



The temperature in the aerogel is determined from the simple model and measurement of the ^{3}He-B VWR damping. The heat capacity is plotted against this. The dramatic peak in the heat capacity occurs at a temperature of approximately 120 μK. Future work will tell us if this feature always occurs at the same temperature.



We can also determine the heat capacity from the heating following a step magnetic field change. The magnitude of the heat capacity is much greater than that of ^{3}He-B, and cannot arise from paramagnetic solid ^{3}He layers as ~270 layers would be needed. We suggest that we are approaching a ferromagnetic state with a heat capacity per atom given (very approximately) by:

$$C \sim k_B(\mu B/k_B)^2(T+\theta)/(T-\theta)^3$$

with a Curie-Weiss temperature, θ, of ~150 μK and 2 layers of solid, whereas published NMR magnetisation measurements[3] on aerogel suggest a Curie-Weiss temperature of ~ 400 μK.