The dynamics of the superfluid ^{3}He AB interface at low temperatures

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We present a model for friction on the moving superfluid ^{3}He AB interface due to orbital viscosity in the B phase texture close to the interface [1]. This model provides a reasonable fit to experimental data, measured at 0 bar pressure and in the low temperature limit of $\sim 0.15 T_C$. The model is applied to an experiment in which the AB interface was stabilised in a magnetic field gradient at the position of the transition field $B_C = 340\,\text{mT}$, and then oscillated at frequencies in the range 0.1 to 100 Hz, by oscillating the position of B_C. Friction on the moving interface gave rise to dissipation that did not fit any simple linear model, and with values greater than any theoretical predictions. The new model gives good fits to the data with a contribution from orbital viscosity that is in good agreement with calculated values.

The AB interface is the most ordered interface available for experimental study [2]. The two bulk phases have different symmetries, with well-understood and established order parameters. When an interface between A and B is stabilised, the order parameter varies smoothly between the two, passing through a planar-like state [3]. In thermodynamic terms the phase transition between A and B is first order with a corresponding latent heat of transition [4, 5], and the interface has an associated surface tension [6, 7].

The analogies between the order parameters of superfluid ^{3}He and those describing other fundamental system allow us to use the superfluid as a model system for the experimental investigation of a broad range of phenomena [8]. For instance the structure of the order parameters which develop as the fluid passes through symmetry-breaking phase transitions are similar to the broken symmetries of the metric of the Universe. The superfluid thus provides a test-bed for the study of transitions in the quantum vacuum state of the early Universe, and the phase interface between the A and B condensates can simulate a 2-brane.

Here we focus on the dynamical behaviour of the AB interface. Previous work by Buchanan *et al* measured the friction on a fast- and freely-moving interface, with values for dissipation that were in line with theoretical estimates based on the Andreev scattering of quasiparticle excitations [9]. Later measurements were made in Lancaster on an interface that was stabilised and driven into controlled oscillation using shaped magnetic field profiles, and at much lower temperatures where pair-breaking was expected to dominate the dissipation. However it was found that the friction was orders of magnitude higher than theoretical predictions [2]. Furthermore, the dissipation showed non-linear behaviour that appeared to depend on the frequency of oscillation of the interface.

We have now shown that orbital viscosity [10] can account for some of this behaviour by considering motion of the B phase order parameter texture that is created by a magnetic field and distorted by the AB interface.

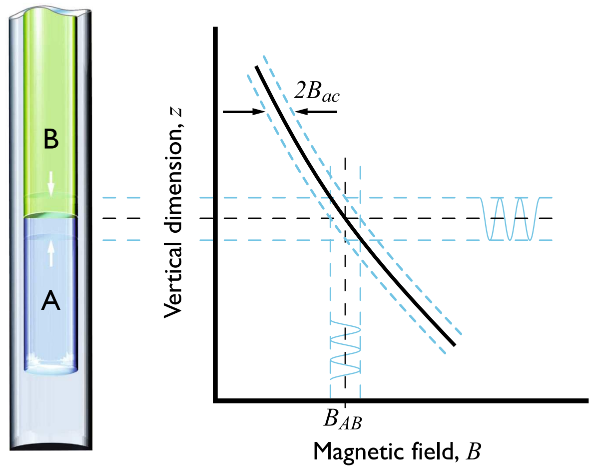

Figure 1: The bottom end of the sapphire black body radiator contains A phase in the bottom and B phase in the top. The A-B interface is stabilised at a position z eq corresponding to the transition field B_c by a shaped magnetic field profile (solid line) provided by the solenoid stack. Oscillating the field profile oscillates the equilibrium position z eq along the cell axis. The oscillatory response of the A-B interface depends on its effective mass and friction.

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