Comment on "Nucleation and Interfacial Coupling between Pure and Dirty Superfluid Phases of ^{3}He"

In a recent Letter Gervais *et al.* [1] reported an experiment on the nucleation of superfluid ^{3}He-B from superfluid ^{3}He-A within 98% silica aerogel. The authors measured the acoustic impedance of liquid ^{3}He confined in a thin aerogel disk grown between two quartz transducers. The measured impedance was sensitive to superfluid phase transitions both in the liquid ^{3}He confined in the aerogel and in the surrounding bulk liquid. The transitions were measured as a function of temperature during warming and cooling for various magnetic fields. On the assumption that there was no superheating of the in-aerogel $B \rightarrow A$ phase transition, the authors deduced a field vs temperature phase diagram published in a previous Letter [2]. On cooling they found the $A \rightarrow B$ transition for the in-aerogel superfluid to occur at substantially lower temperatures [1]. The authors interpreted these results in terms of a barrier for the nucleation of the B phase in aerogel despite the surrounding bulk B phase which might have been expected to provide an effective nucleation seed for the liquid in the aerogel. The authors suggested an explanation in terms of "decoherence of the dirty superfluid order parameter on the scale of the critical radius."

Here we point out that these observations can be more simply explained without recourse to a nucleation barrier for either $A \rightarrow B$ or $B \rightarrow A$ transitions in the aerogel. The effects attributed to the proposed nucleation barriers arise more naturally from the action of pinning of the phase boundary in the aerogel, the occurrence of which is already well established in this system [3]. Further, if pinning is indeed the dominant factor, then we expect both apparent superheating and supercooling of the transition with the true thermodynamic phase transition lying between the observed transitions on cooling and warming. This would significantly change the phase diagram inferred by the authors, implying a region close to T_c where the A phase is the thermodynamically stable phase in aerogel in zero magnetic field at the higher pressures.

Consider the following mechanism in the aerogel. Assume there are no barriers to nucleation but significant pinning of the A-B interface. On cooling the A phase through the thermodynamic $A \rightarrow B$ phase transition temperature, the B phase may nucleate at favorable locations within the aerogel. However, since the pinned A-B interface cannot freely expand, the majority of the liquid in the aerogel remains in the A phase. Since the driving force on the interface is given by the free energy difference between the two phases, the transition can be complete throughout the aerogel only when the free energy difference between the phases is sufficient to overcome the interfacial pinning energy. In other words, the B phase can expand through the aerogel only after sufficient supercooling has been achieved. Conversely, on warming with the B phase within the aerogel, the A phase will nucleate at favorable locations in the aerogel, but again the phase boundary cannot expand until there is sufficient superheating to overcome the pinning. Therefore the two transitions observed on warming and cooling will bracket the true thermodynamic phase transition.

Given that the influence of pinning on the motion of the A-B interface in aerogel has already been observed [3], how can the above scenario be experimentally distinguished from the nucleation barrier mechanism proposed in Ref. [1]? Evidence in favor of pinning comes from the observed widths of the transitions on both cooling and warming, apparent from the authors' earlier Letter [2]. A finite width for both transitions, in the pinning scenario, is a natural consequence of a spread of pinning energies within the aerogel. Furthermore, if no pinning were involved and the B-phase nucleations limited only by a nucleation barrier, then why is the transition not sharp (as observed in the bulk superfluid transitions)? The only possibility we can envisage is that the interface motion might be heavily damped yielding a finite time to sweep through the aerogel. However, the observed width of the transition is found to be independent of the warming/cooling rate [4]. We therefore suggest that the pinning scenario offers a simpler explanation of the experiments described in Refs. [1] and [2] obviating the need to invoke novel nucleation or decoherence properties of the superfluid ^{3}He in the aerogel.

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