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Comment on “Nucleation of $^3$He-B from the A Phase: A Cosmic-Ray Effect?”

In an interesting Letter, Leggett\(^1\) suggests that the nucleation of $^3$He-B from the metastable A phase is a consequence of the passage of a cosmic ray through the sample cell. Here we present new experimental data obtained with a rotating cryostat in NMR experiments\(^2\) on $^3$He. Figure 1(a) shows our data, taken on the $A \rightarrow B$ transition in magnetic fields of 28.4 and 56.9 mT; no field dependence was found between these values. We find that supercooling of the A phase into the B phase is substantial, and there appears to be a threshold temperature ("catastrophe line") $T_{\text{AB}}(p) \nless T_{\text{AB}}(p)$, where the metastable A phase first changes into $^3$He-B.

We want to emphasize that in our $^3$He cell the $A \rightarrow B$ transition could only be observed during cooling, never on warmup. The cooling rate varied between 5 and 29 $\mu$K/min, but no clear dependence of B-phase nucleation on the cooling rate could be established. When the temperature was stable, the A phase was found to persist, and no $A \rightarrow B$ transition was ever observed in this case. For example, at $p = 29.3$ bars (with $T_{\text{AB}} = 0.85T_c$) and 28.4 mT, the A liquid was cooled as low as $T_{\text{min}} = 0.67T_c$, and was maintained below $0.7T_c$ for 2 h; in this run the metastable A phase persisted a total of 8 h, never nucleating the B phase. The temperatures in Fig. 1 are upper-bound estimates for $T_{\text{AB}}$. They are determined from NMR susceptibility measurements on platinum powder immersed in the $^3$He. A comparison with the A-phase NMR frequency-shift measurement shows that on cooling, the platinum temperature lags behind, at a cooling rate of 20–30 $\mu$K/min by $\leq 0.02T_c/T_c$. Even lower liquid temperatures exist in the heat exchanger between the $^3$He sample and the refrigerator.

Figure 1(b) represents the data points at 29.3 bars as a histogram and compares them with a fitted distribution of nucleation probability. We conclude that experimentally the nucleation mechanism appears to be active only in a narrow temperature interval near the "catastrophe line" well below the thermodynamic $A \rightarrow B$ transition. An interesting point to note is that on cooling through the $A \rightarrow B$ transition during rotation, the A phase stayed supercooled as long as in the stationary liquid. This is further (indirect) evidence in support of the conclusion\(^1\) that continuous vortices are induced by rotation in a bulk liquid sample of $^3$He-A.

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