Comment on "Stabilized Pair Density Wave via Nanoscale Confinement of Superfluid ^{3}He"

In a recent Letter, A. J. Shook *et al.* reported mass transport anomalies in superfluid ^{3}He confined in three nanomechanical Helmholtz resonators as signatures of transitions between three superfluid phases and proposed the intermediate phase to be a pair density wave (PDW) [1]. In this Comment, we show that, in contrast to this claim, the pairs of closely spaced anomalies in each resonator, open and filled green circles in Fig. 4 of the Letter, are rather signatures of a transition between two superfluid phases in regions of different confinement.

Each resonator consists of the central basin of one uniform thickness and two channels of another, Fig. 1(a). The *mass-on-a-spring* description of the resonator [2] used in the Letter attributes the shifts in the resonance frequency to the change in the superfluid fraction of ^{3}He in the channels, which acts as the oscillating mass. This model overlooks the contribution to the oscillating mass of sizeable fast-moving regions of the basin adjacent to the channels, Fig. 1(a), and the possible flow across a phase boundary at the channel-basin interface. Therefore, the interpretation of the resonator response should consider the superfluid in the channels and in the basin.

The reported anomalies shift to lower temperatures with decreasing resonator size, characteristic of phase transitions driven by confinement [4]. In a given resonator, any such transition would occur at different temperatures within the channels and basin of unequal thickness. Figure 1(b) reproduces the anomalies observed in the 0.6 μm resonator and the Ginzburg–Landau calculation of the transition between the superfluid A and B phases in the $D = 636$ nm channels [[1], Fig. 4(d)]. To these we add the same A-B line rescaled to the basin thickness $D = 577$ nm [3]. We conclude that the two anomalies are well described by the predicted A-B transition in the channels and the basin. The same scenario accounts for the observations in the 0.8 and 1.0 μm resonators.

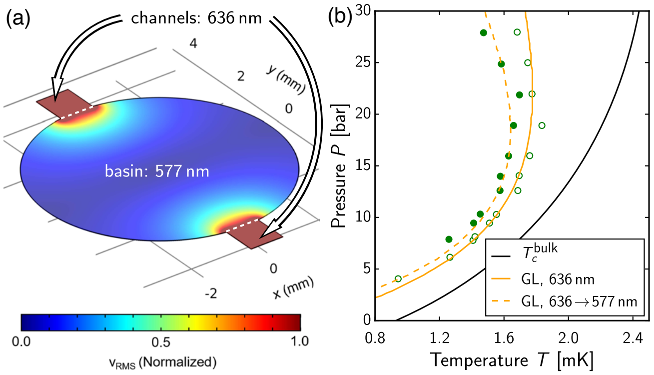

FIG. 1. Transport anomalies attributed by Shook *et al.* to a PDW in the 0.6 μm resonator [1]. (a) Channels and basin of the resonator of different thickness superimposed with the model of velocity field [[1], Supplemental Material]. Both the channels and the basin contribute to the resonator response. (b) The phase diagram reported by Shook *et al.* [[1], Fig. 4(d)] with the Ginzburg–Landau calculation of the A-B boundary (GL) rescaled to the basin thickness [3]. The upper and lower anomalies, open and filled green circles, are consistent with signatures of the same phase transition in channels and basin. The bulk superfluid transition T_c^{bulk} is shown for reference.

If a sequence of two transitions associated with a PDW occurred in the resonator channels, as proposed by Shook *et al.*, each would also occur in the basin at a lower temperature. These extra signatures were not reported.

Finally, we clarify the nuclear magnetic resonance (NMR) signature of a PDW [5] and the distinction between soft and hard domain walls in the B phase [6], since the account in the Letter is incorrect. The coexistence of positively and negatively shifted NMR lines corresponds to a soft domain wall between wide ($\gg 10$ μm) domains with different spin-orbit orientations [7]. In contrast the PDW identified in Ref. [5] is an array of hard domain walls separating narrow ($\ll 10$ μm) domains with opposite sign of one of the pairing amplitudes. It results in a single NMR line with a tip-angle-dependent frequency shift, sensitive to the overall spin-orbit orientation and the relative population of the $+/-$ domains. In these measurements performed at low pressure [5], the pressure-induced bowing of the ^{3}He cavity had insignificant subnanometer effect on the uniformity of its thickness, contrary to the Letter's assertion.

Lev V. Levitin,[1,*] Xavier Rojas,[1] Petri J. Heikkinen,[1]
Andrew J. Casey,[1] Jeevak M. Parpia[2] and John Saunders[1]
[1]Department of Physics
Royal Holloway University of London
Egham, Surrey TW20 0EX
United Kingdom
[2]Department of Physics
Cornell University
Ithaca
New York 14853, USA

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[*] Corresponding author.
l.v.levitin@rhul.ac.uk

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