From BCS to Bose superfluidity in two-dimensional Fermi gases: Renormalization group and tighter upper bounds for the critical temperature

Carlos A. R. Sá de Melo

Georgia Institute of Technology
Atlanta, GA, USA

I discuss two-dimensional (2D) superfluidity from the Bardeen-Cooper-Schrieffer to the Bose regimes in Fermi gases. In the first lecture, I introduce the Berezinskii-Kosterlitz-Thouless mechanism of superfluidity and its critical temperature [1] and start a discussion of the low-energy collective modes as a function of the scattering parameter (binding energy) [2]. I also reveal some experimental and theoretical issues that need to be addressed [3]. In the second lecture, I finalize the analysis of low-energy collective modes by comparing theory and experiment for 2D box potentials [2]. In addition, I discuss the importance of the renormalization of the superfluid density in obtaining tighter upper bounds for the critical temperature (T_c) of 2D superfluids. Lastly, I emphasize that standard upper bounds on T_c (based on the kinetic energy or the unrenormalized superfluid density) are not tight, because they do not include the effects of interactions or density on the chemical potential and vortex core energy. [4]

References:

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[2] Senne Van Loon and C. A. R. Sá de Melo, "Effects of Quantum Fluctuations on the Low-Energy Collective Modes of Two-Dimensional Superfluid Fermi Gases from the BCS to the Bose Limit", Phys. Rev. Lett. **131**, 113001 (2023).
[3] C. A. R. Sá de Melo and Senne Van Loon, "Evolution from Bardeen-Cooper-Schriefer to Bose-Einstein Condensation in two dimensions: Crossovers and topological quantum phase transitions", Ann. Rev. Cond. Matt. Phys. **15**, 109 (2024).
[4] T. Shi, W. Zhang, and C. A. R. Sá de Melo, "Tighter upper bounds on the critical temperature of two-dimensional superconductors and superfluids from the BCS to the Bose regime", ArXiv:2303.10939v1 (2023).