Multiple Quasiparticle Bound States in a Trap Created by a Local Superconducting Gap Variation

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At low temperature, the concentration of quasiparticles observed in superconducting circuits far exceeds the predictions of microscopic BCS theory at equilibrium. As a source of dissipation, these excess quasiparticles degrade the performance of various devices. Therefore, understanding their dynamics, especially their recombination into Cooper pairs, is an active topic of current research. In disordered superconductors, spatial fluctuations in the superconducting gap can trap quasiparticles and modify their eigenspectrum. Since this spectrum plays a key role in quasiparticle dynamics, it must be carefully investigated.

To this end, we introduce a toy model of a single trap. Specifically, we consider a shallow disk-shaped gap variation in a clean two-dimensional superconductor. Using semiclassical theory, we demonstrate the existence of multiple bound states depending on the radius and depth of the trap. Extending our analysis beyond the semiclassical regime, we observe an infinite number of bound states very close to the gap edge, even for an arbitrarily small trap. These results deepen our understanding of trapped quasiparticles and may have important implications for their recombination in disordered superconductors.

Figure

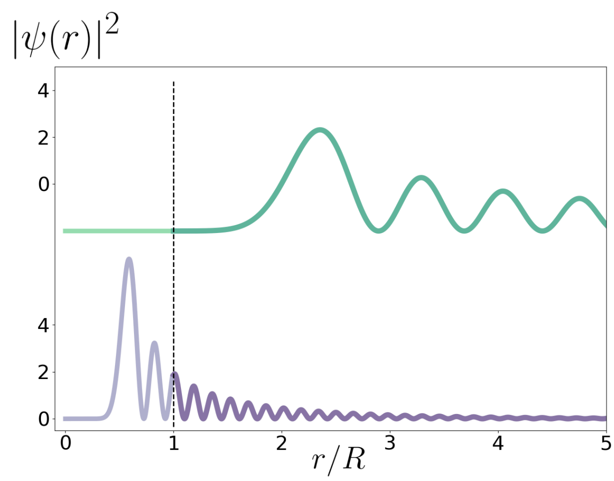

Figure 1: Sketch of the wavefunctions of different types of bound states in a trap with radius R. The curve in purple shows an eigenstate localized mainly inside the trap, which is captured by semiclassics. The curve in green shows an eigenstate localized mainly outside the trap, which is beyond semiclassics.

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