

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

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Quasiparticle-induced dissipation degrades the performance of superconducting devices, such as qubits and resonators [1]. In disordered superconductors, local variations may trap quasiparticles [2], modifying the subgap spectrum and hindering Cooper-pair recombination [3]. Despite existing studies, a systematic description of the bound state spectrum as a function of trap size remains lacking. To this end, we introduce a toy model of a single disk-shaped gap variation in a clean superconductor [4]. Within a semiclassical framework, we find multiple bound states whose number depends on trap size and depth. While semiclassics accurately describe states sufficiently far from the gap edge in large traps, a full Bogoliubov-de Gennes analysis reveals that in dimensions higher than one, an infinite number of bound states accumulate near the gap edge, even for an arbitrarily weak trap. This work provides an exact description of quasiparticle bound states across all trap sizes and has direct implications for recombination processes .

References

- [1] Aumentado, Catelani, Serniak; *Physics Today* 76 (8), 34, (2023)
- [2] Larkin, Ovchinnikov, *Sov. Phys. JETP* 34, 1144 (1972)
- [3] Beshpalov, Houzet, Meyer, Nazarov, *PRL* 117, 117002 (2016)
- [4] Morin, Basko, Houzet, Meyer, arXiv:2512.15580, 2025

Figures

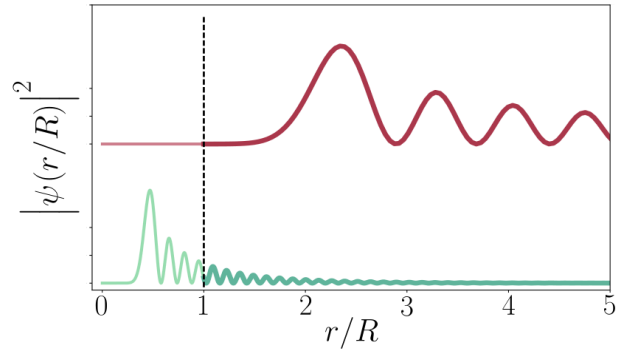


Figure 1: Sketch of bound-state wave functions in a trap of radius R : semiclassical state localized mainly inside (green) and non-semiclassical state localized mainly outside (red).

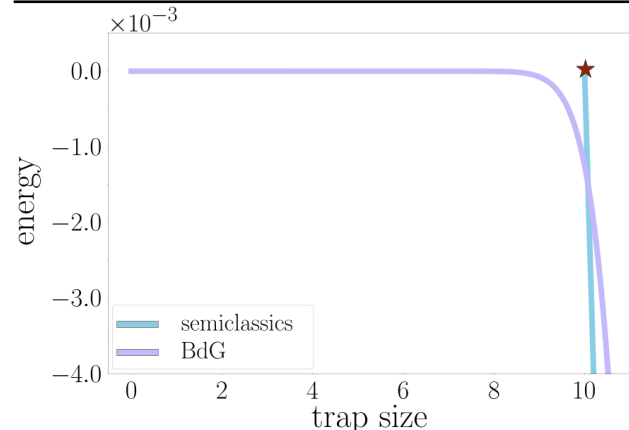


Figure 2: Bound-state energy for angular momentum $l > 0$, measured from the gap edge, as a function of the trap size. The BdG solution (purple) shows that a bound state exists for all trap sizes, while the semiclassical solution (blue) exists only above a threshold trap size (red star).