Flux periodicities in loops of nodal superconductors

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The magnetic flux periodicity of superconducting loops as well as flux quantization itself are a manifestation of macroscopic quantum phenomena with far reaching implications. They provide the key to the understanding of many fundamental properties of superconductors. In superconducting rings the electrical current has been known to periodically respond to a magnetic flux with a periodicity of $hc/2e$. The $hc/2e$ periodicity is viewed to be a hallmark for electronic pairing in superconductors and is considered evidence for the existence of Cooper pairs. Here we show that in contrast to this long-term belief, rings of many superconductors bear an hc/e periodicity instead. For nodal superconductors, the flux induced Doppler shift of the near-nodal states leads to a flux dependent occupation probability of quasi particles circulating clockwise and counter clockwise around the loop, which results in am hc/e periodic component of the supercurrent, even at zero temperature. We analyze this phenomenon in an analytic approach and also numerically—both within the framework of conventional BCS theory. Specifically for *d*-wave pairing, we show that the hc/e periodic current component decreases with the inverse radius of the loop.

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