Vortex-core states, conductance modulations and Lifshitz transition revealed by Scanning Tunneling Spectroscopy in $Bi_2Sr_2CaCu_2O_{8+\delta}$

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Abstract

The electronic structure of the Abrikosov vortices is one of the outstanding puzzles of high temperature superconductivity (HTS) [1]. For long, vortices explored with Scanning Tunneling Microscopy in HTS cuprates were systematically lacking the electronic signatures predicted by Wang and MacDonald for d-wave superconductors [2]. It is only recently that the zero-bias conductance peak expected from theory at the center of the flux lines was observed in heavily-overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) single crystals [3]. However, other vortex cores measured in similar regimes still reveal the unusual electronic features reported previously, including periodic conductance modulations in the vortex halos and low energy subgap states. We present here how these electronic states and charge orders evolve in a broad doping range. At a doping level of $p \sim 0.21$, we find striking transformations in the electronic structure of the vortex halos: the checkerboard modulations vanish, and a pronounced zero-bias anomaly emerges. This abrupt change is consistent with a Lifshitz transition, which involves a significant reconstruction of the Fermi surface topology, and may be indicative of an underlying quantum critical point.

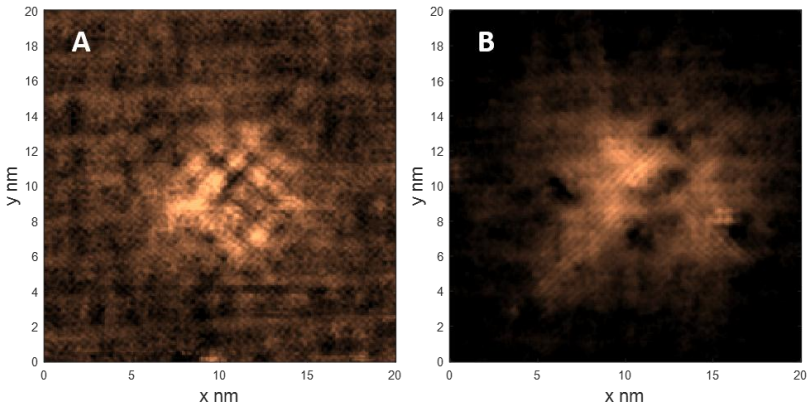

Figure 1 :20x20 nm 5mV spectroscopic maps of a vortex halo in Bi-2212 at $p < 0.21$ (A) and $p > 0.21$ (B) hole doping (from [3]).

References

[1] I. Maggio-Aprile et al., Physica C 615, 1354386 (2023).

[2] Y. Wang and A. H. MacDonald, Physical Review B 52, R3876 (1995).

[3] T. Gazdić, I. Maggio-Aprile, G. Gu and Ch. Renner, Physical Review X 11, 031040 (2021).

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