Wang-McDonald vortex core states in heavily-overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$

Ivan Maggio-Aprile,[1] Tim Gazdić,[1] Christophe Berthod,[1] Louk Rademaker,[1] Genda Gu,[2] and Christoph Renner[1]

[1] *DQMP, Université de Genève, SUISSE*
[2] *Brookhaven Nat. Lab., New-York, USA*

The electronic signature of vortex cores in high-temperature cuprate superconductors has been challenging the scientific community for decades. Early experiments were suggesting that the cores in these materials were not matching the BCS expectations, one of the main argument being that the zero-bias conductance anomaly predicted for d-wave superconductors by Wang and MacDonald in 1995 [1] was absent. In 2016, we found that the previously reported subgap states in $YBa_2Cu_3O_{7-\delta}$ (Y123) were belonging to an electronic background uniformly measured across the surface [2], and could demonstrate that the vortex cores in Y123 do really present the expected BCS quasiparticle LDOS [3]. From recent scanning tunneling microscopy data [4], we show that vortices observed at very low magnetic field in heavily overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ do exhibit a clear d-wave electronic structure, with a zero-bias conductance peak at the vortex center that splits with increasing distance from the core. We stress that previously reported unconventional electronic structures, like the low energy conductance modulations in the vortex halo and the absence of a zero-bias conductance peak at the vortex center, are direct consequences of short inter-vortex distance and vortex-vortex interactions prevailing in earlier experiments. Whether these characteristics are restricted to strong overdoping is the focus of ongoing measurements on heavily underdoped samples, where the electronic signatures are significantly dominated by the pseudogap regime. We also aim at studying the widely debated topic of charge density modulations as well as the theoretically predicted pair density waves, in order to confirm their existence or absence at the various doping regimes.

[1] Y. Wang and A. H. MacDonald, Physical Review B 52, R3876 (1995).
[2] J. Bruer et al., Nat. Commun. 7, 11139 (2016).
[3] C. Berthod et al., Phys. Rev. Lett. 119, 237001 (2017).
[4] Tim Gazdić et al., arXiv:2103.05994 (to be published in Phys. Rev. X - 2021).