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Vortices in unconventional superconductors

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Over thirty years ago, the high-temperature cuprate superconductors were discovered, and although many of the phenomenological tools developed to describe superconductivity could still be applied, the Bardeen-Cooper-Schrieffer (BCS) theory for superconductors was found not to work. It became clear that a Cooper pair of electrons formed, but that the superconducting energy gap had become more complicated. At the same time, other families of so-called 'unconventional' superconducting states were being discovered, creating a complicated landscape where quantitative predictions have proved elusive. Many varied experimental techniques have been deployed on these materials.
Most of these unconventional superconductors fall into the class known as Type-II, meaning that above a certain critical field, magnetic field can penetrate deep into the material, but only in the form of lines of magnetic flux, creating magnetic vortices. This creates a network of normal (non-superconducting) state in the vortex core. These vortices are very sensitive to the nature of the superconductivity and can tell us about properties like the London penetration depth (how far magnetic field extends into the pure superconducting state) and the coherence length (roughly the size of the Cooper pair). Using neutron diffraction, we can explore how these properties vary throughout the superconducting phase of a material, and then compare with other experimental and theoretical results. In some cases, we observe unexpected deviations, and in this talk I will explore what we can conclude from this [1-3].

References

[1] E. Campillo et al., Phys. Rev. B 104, 184508 (2021).
[2] E. Campillo et al., Phys. Rev. B 105, 184508 (2022).
[3] A. Cameron & E. Campillo et al., arXiv:2208:06706 (2022).

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