Contribution ID: **106** Type: **not specified**

Modelling of vortex core magnetization and Pauli paramagnetic effects

To better understand the behaviour of $CeCu_2Si_2$ and other Pauli limited superconductors, we present a physically-based expression for the size and magnetisation of the vortex cores in Pauli-limited superconductors, based on the results of first-principles computations [1].

Unconventional superconductors, with pairing mechanisms and properties that are not accounted for BCS theory are a subject of continuing interest.
%One example is heavy-fermion materials, in which the charge carriers respond as if they had a mass many times that of a free electron. The first heavy-fermion superconductor to be discovered (1979) was $CeCu_2Si_2$ [2] but a lot of questions remain over the nature of its superconducting state.

We have studied the vortex lattice (VL) that develops inside $CeCu_2Si_2$ [2] when a magnetic field is applied. The magnetic field in the VL may be expressed as a sum of Fourier components in momentum-space and the magnitude of each Fourier component as a function of field or temperature, often called the 'form factor' (FF). This can be extracted from the measured integrated neutron scattering (SANS) intensity [3] and contains information about the magnetic field distribution inside and outside the vortex cores.

We find that $CeCu_2Si_2$ shows a strong increase of SANS intensity from the flux lines as the applied field is increased towards the edge of the superconducting phase [4]. This has previously been observed in $CeCoIn_5$ [5] (Figure 1) and indicates that the superconductivity in this material is not destroyed by the same mechanism as in almost all other superconductors but instead by Pauli paramagnetic effects (PPE) [6]. It is thought to be responsible for weaker anomalies in the form factor seen in $TmNi_2B_2C$ [7] and $YBa_2Cu_3O_7$ [8,9].

Relying on the results of first-principles numerical calculations, we have obtained algebraic expressions which indicate how the size and magnetisation of the vortex cores varies with field and hence obtain general results for the variation of the SANS intensity / VL form factor as a function of field and temperature for superconductors exhibiting PPE.

Furthermore, in our work on YBCO and Ca-doped YBCO [9,10], there are deviations from the London model at the highest fields measured (Figure 2), which may suggest speculated that Pauli paramagnetic effects are responsible, and the next step would be to apply our model to this data.

[1] Ichioka, M. & Machida, *Phys. Rev. B* **76**, 064502 (2007).
[2] Steglich, F. *et al.*, *Phys. Rev. Lett.*, **43**, 1892 (1979).
[3] Christen H. D. *et al.*, *Phys. Rev. B*, **15**, 4506 (1977).
[4] Campillo, E. *et al.*, *Phys. Rev. B*, **104**, 184508 (2021).
[5] Bianchi, A. D. *et al.*, *Science*, **319**, 177–180 (2008).
[6] Clogston, A. M., *Phys. Rev. Lett.*, **9**, 266 (1962).
[7] DeBeer-Schmitt, L. *et al.*, *Phys. Rev. Lett.*, **99**, 167001 (2007).
[8] Cameron, A. *et al.*, *Phys. Rev. B*, **90**, 054502 (2014).
[9] Campillo, E. *et al.*, *arXiv preprint arXiv:2203.01705* (2022).
[10] Cameron, A. & Campillo, E. *et al.*, *In preparation.*
[11] White, J. S. *et al.*, *Journal of Physics*, **12**, 023026 (2010).

Author: CAMPILLO, Emma (Lund University)

Co-authors: Prof. BLACKBURN, Elizabeth (Lund University); Prof. M. FORGAN, Edward (University of Birmingham)

Presenter: CAMPILLO, Emma (Lund University)

Session Classification: Plenary session

Track Classification: Posters