Theory of Quasiparticle Excitations in Vortices of Iron Pnictide Superconductors

Y. Wang, J.S. Kim, G.R. Stewart, P.J. Hirschfeld (UF Physics); I. Vekhter (LSU)

Introduction

The discovery of superconductivity at ~50K in the FeAs-based materials has caused considerable excitement in the condensed matter community. At present experiments on the superconducting state present many apparent paradoxes, with some interpreted in terms of a fully gapped superconducting state, and others indicating low-energy excitations[1]. It is believed that most of these differences arise due to differences in electronic structure and local interactions, which lead to "anisotropic sign-changing s-wave" order[2], as shown in Fig. 1a. We investigated the excitations in such states in the vortex state, by calculating the electronic structure of a single vortex within the quasiclassical (Eilenberger) approximation, allowing us to investigate both the local density of states as probed by STM, and the contribution of such excitations to thermodynamic properties like specific heat.

Results and Discussion

The vortex bound states in anisotropic multiband s-wave superconductors are not terribly unusual. In general, the low-energy states have a spatial structure with tails extending in the direction of deep gap minima or nodes, as, e.g. in the d-wave case. However in special circumstances Fermi surface anisotropy can weight quasiparticle trajectories so as to confuse the issue. In Ref. [3] we showed this could be the case in LiFeAs, the best candidate for clean STM imaging of these states. The C/T vs. H of such superconductors can show a Volovik type √H behavior over a limited field range arising from the nodes or deep gap minima on one sheet, which then crosses over to a linear-H behavior expected for a classic s-wave system.

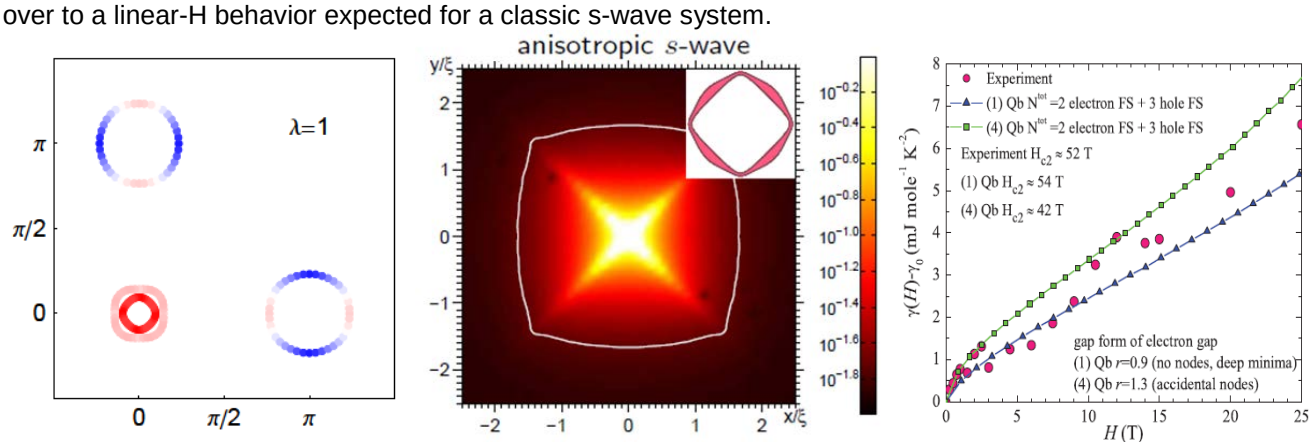

Figure 1 (Left) Sign-changing s-wave state with nodes on the β Fermi surfaces. The *s*-wave state changes sign between sheets, but may also exhibit nodes on the β sheets. The clean order parameter on the β sheets is defined as $\Delta=\Delta_0(1+r\cos 2\phi)$. (Middle) Density of quasiparticle states in vortex core for single diamond-shaped Fermi surface sheet appropriate for LiFeAs showing tails along *antinodal* directions (gap structure is shown in insert)[3]. (Right) Specific heat vs. field for a gap similar to plot on left, with nodes (r>1) or deep gap minima (r<1), both providing reasonable fits to data of Stewart group on BaFe2(As1-x Px)2 [4]. Data on Ba(Fe1-xCo)2As2 were also analyzed[5].

Conclusions

The superconducting state in most Fe-based superconductors is probably of multiband anisotropic s type. Depending on the details of the low-energy electronic structure, both relatively gap structures and states with clear nodes can be obtained. The study of vortex physics in such systems can aid in determining gap symmetry.

Acknowledgements

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References

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