Theory of Spin Fluctuation Pairing in Iron Pnictide Superconductors

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Introduction

The discovery of superconductivity at ~50K in the FeAs-based materials has once again galvanized interest in a new class of superconductors, and raised questions of how similar and different are these new systems relative to the cuprates. Weak-coupling approaches to the pairing problem in the iron pnictide superconductors have predicted a wide variety of superconducting ground states. We performed Random Phase Approximation (RPA) calculations of the magnetic susceptibility and pairing interaction within a 5-band model accounting for Hubbard and Hund's rule interactions on each Fe site. We discuss the robustness of these results for different dopings, interaction strengths, and variations in band structure. Within the parameter space explored, an anisotropic, sign-changing *s*-wave state and a *d* state are nearly degenerate, due to the near nesting of Fermi surface sheets. The near degeneracy is a natural consequence of the nearly nested cylindrical Fermi sheets, and may give rise to interesting new phenomena such as order parameter collective modes[1].

Results and Discussion

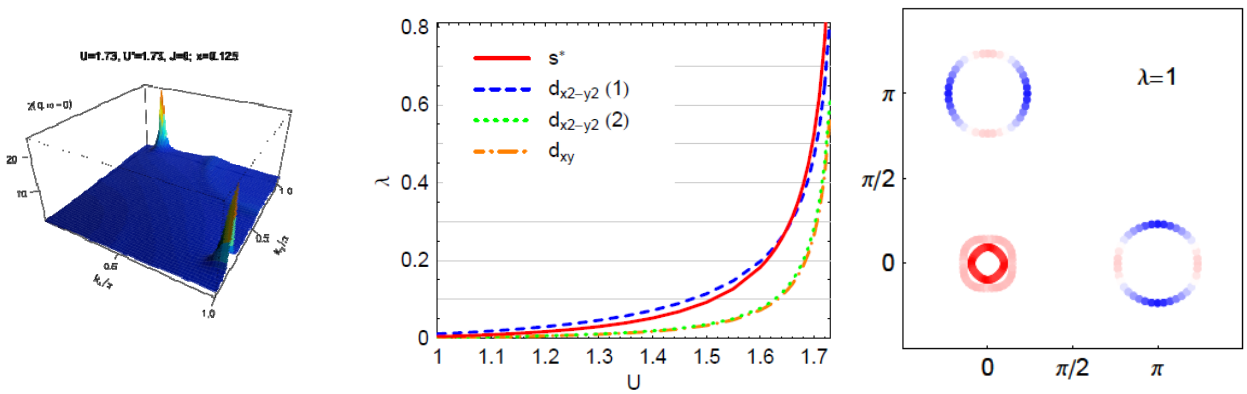

Figure 1 (Left) RPA static magnetic susceptibility vs. q near the for a choice of Hubbard U, intraorbital U', Hund's rule couplings J and J'. (Middle) Dependence of pairing eigenvalue λ on Hubbard interaction in various pairing channels. (Right) Sign-changing s-wave state with nodes on the β Fermi surfaces.

The 5-band model was based on the Density Functional Theory (DFT) calculations of Cao et al. and yields a Fermi surface shown in Fig. 1(c). For undoped systems the peak in $\chi(q,\omega)$ at $(\pi,0)$ in the reduced Brillouin zone, but at finite doping and Hund's rule coupling becomes incommensurate, as shown in Fig. 1(a). The pairing interaction arises overwhelmingly from spin fluctuations near this point. Because of the near nesting of the Fermi surface sheets, a *d*-wave $\cos k_x - \cos k_y$ state and *s*-wave $\cos k_x + \cos k_y$ state have the highest pairing eigenvalues. The *s*-wave state changes sign between sheets, but also exhibits nodes on the β sheets.

Conclusions

The near-degeneracy of several pairing states may account for the fact that in different materials with different dopings both indications of isotropic quasiparticle spectrum as well as nodes have been reported. Collective modes of the Bardasis-Schrieffer type may be visible in optics and Raman experiments. Within the interaction parameter set we explored, nodes were robust, but in the case of the *s*-wave (A_{1g}) state found will be lifted by disorder. This is another possible explanation for the observation of isotropic spectrum as observed, e.g. in photoemission. If low energy excitations are observed, we proposed that the best way to determine the topology of nodal states in bulk materials is to perform a specific heat experiment in rotating magnetic field[3].

Acknowledgements

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References

[1] S. Graser et al, arXiv:0812.0343
[2] C. Cao, P.J.Hirschfeld, and H.-P. Cheng, Phys. Rev. B 77, 220506 (2008).
[3] S. Graser et al., Phys. Rev. B77, 180514 (2008)..