Yu-Shiba-Rusinov states in 2D superconductors with arbitrary Fermi contours

Jon Ortuzar Andres
Stefano Trivini, Mikel Rouco, Javier Zaldivar, Jose Ignacio Pascual, and F. Sebastian Bergeret.

CFM, Paseo de Manuel Lardizabal, 5, 20018, Donostia-San Sebastian, Spain

jon.ortuzar.a@gmail.com

Abstract

Magnetic impurities on a superconductor induce sub-gap Yu-Shiba-Rusinov (YSR) bound states, localized at the impurity site, and fading away from it for distances up to several nanometers [1,2]. In this article, we present a theoretical method to calculate the spatial distribution of the YSR spectrum of a two-dimensional superconductor with arbitrary Fermi contours (FCs) in the presence of magnetic impurities. Based on the Green's Function (GF) formalism, we obtain a general analytical expression by approximating an arbitrary contour shape to a regular polygon. This method allows us to show the connection between the spatial decay (and, hence, the extension) of YSR states and the shape of the FC of the host superconductor. We further apply this formalism to compute the evolution of YSR states in the presence of a nearby impurity atom [3] and compare the results with Scanning Tunneling Microscopy (STM) measurements on interacting manganese dimers on the β-Bi_2Pd superconductor. The method can be easily extended to any arbitrary number of magnetically coupled impurities, thus providing a useful tool for simulating the spectral properties of interacting YSR states in artificial atomic nanostructures.

References

[1] H. Kim, L. Rózsa, D. Schreyer, E. Simon, and R. Wiesendanger, Nat. Commun. (2020) 11, 1.

[2] G. C. M´enard, S. Guissart, C. Brun, S. Pons, V. S. Stol-yarov, F. Debontridder, M. V. Leclerc, E. Janod, L. Cario,D. Roditchev, P. Simon, and T. Cren, Nat. Phys. (2015) 11, 1013.

[3] D. J. Choi, C. G. Fernández, E. Herrera, C. Rubio-Verdú, M. M. Ugeda, I. Guillamón, H. Suderow, J. I. Pascual, andN. Lorente, Phys. Rev. Lett. (2018) 120, 1.

Figures

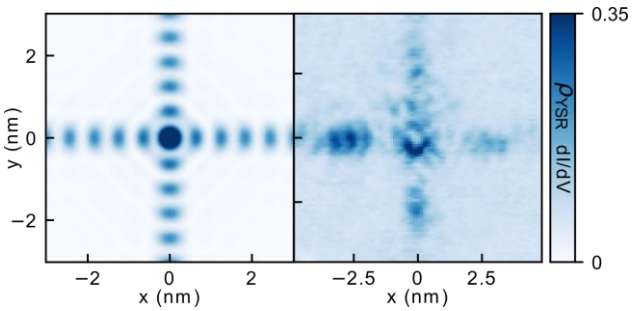

Figure 1: Calculation of the extension of the YSR states for a square-shaped FC (left panel) and dI/dV map of the extension of the YSR of an V adatom on the β-Bi_2Pd surface (right panel).

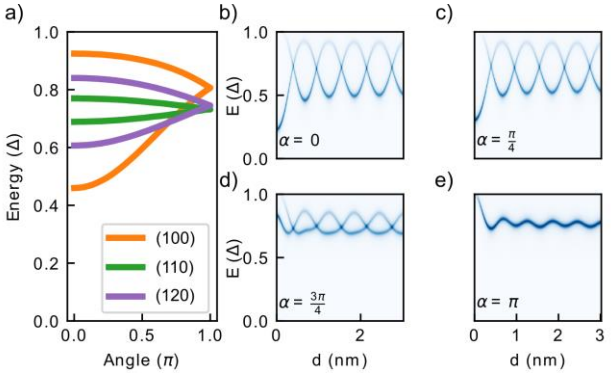

Figure 2: Multiple calculations of the splitting of the YSR states for adatom dimers. (a) Angular dependence of YSR states splitting for the (100), (110) and (120) directions. (b-e) Dependence of the splitting on the relative distance between adatoms for the (100) direction and several relative angles.