Non-local transport and entangled Andreev pairs in hybrid superconducting nanostructures

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Nanoscale superconductors connected to normal metallic electrodes provide a potential source of entangled electron pairs. Such states would arise from the splitting of Cooper pairs in the superconductor into two electrons with opposite spins, which then tunnel into different leads, by means of a process known as crossed Andreev reflection (CAR). In an actual system, the detection of these entangled pairs is hindered by the elastic cotunneling (EC) of individual electrons between the leads, which yields an opposite contribution to the non-local conductance. The simplest theory in fact predicts a complete cancellation between these contributions for a BCS superconductor weakly coupled to non-magnetic leads. In this talk I would present some recent theoretical work which demonstrates that the balance between CAR and EC processes can be broken in several situations:

- When the superconductor is coupled to normal electrodes by small capacitance tunnel junctions and electron interactions have an important influence [1].
- In the case of high-Tc superconductors, where the d-wave character of the order parameter can lead to long-range CAR processes along certain crystal orientations [2]
- At the interface between a BCS superconductor and graphene, where specular Andreev reflections can take place [3].

These findings may help to clarify some intriguing experimental results and provide future strategies for the detection of entangled pairs in solid-state devices.

1) A. Levy Yeyati, F. S. Bergeret, A. Martín-Rodero and T. M. Klapwijk, Nature Physics **3**, 455 (2007).
2) W. Herrera, A. Levy Yeyati and A. Martín-Rodero, to be published.
3) P. Burset, W. Herrera and A. Levy Yeyati, in preparation.