Lecture 4:

Andreev bound states

(SIS junction, quantum dots: Shiba state, Kondo effect vs superconductivity)
PROBABLE OBSERVATION OF THE JOSEPHSON SUPERCONDUCTING TUNNELING EFFECT

P. W. Anderson and J. M. Rowell
Bell Telephone Laboratories, Murray Hill, New Jersey
(Received 11 January 1963)

![Graph showing current-voltage characteristic](image)

**FIG. 1.** Current-voltage characteristic for a tin-tin oxide-lead tunnel structure at \(\sim 1.5\,\text{K}\), (a) for a field of \(6 \times 10^{-3}\) gauss and (b) for a field 0.4 gauss.
IV characteristics of an SIS junction

Al/Al$_2$O$_3$/Al
T=40 mK
Conduction Channel Transmissions of Atomic-Size Aluminum Contacts

E. Scheer, P. Joyez, D.Esteve, C. Urbina,* and M. H. Devoret

Service de Physique de l’Etat Condensé, Commissariat à l’Energie Atomique, Saclay, F-91191 Gif-sur-Yvette Cedex, France
(Received 4 February 1997)
Andreev qubit

Coherent manipulation of Andreev states in superconducting atomic contacts

C. Janvier,1 L. Tosi,1,2 L. Bretheau,1,2 Ç. Ö. Girit,1,2 M. Stern,1 P. Bertet,1 P. Joyez,1 D. Vion,1 D. Esteve,1 M. F. Goffman,1 H. Pothier,1 C. Urbina1,3

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Andreev bound state in quantum dot

Andreev bound states in supercurrent-carrying carbon nanotubes revealed

J-D. Pillet¹, C. H. L. Quay¹, P. Morfin², C. Bena³,⁴, A. Levy Yeyati⁵ and P. Joyez¹ *

1 Institut de Physique Théorique, Ecole Polytechnique, Palaiseau, France
2 Physique de la Matière Condensée, Institut Jean le Rond d’Alembert, UMR 7589, Université Pierre et Marie Curie, 4 place Jussieu, 75252 Paris, France
3 Laboratoire de Physique, Université de Savoie, F-73376 Le Bourget du Lac, France
4 Laboratoire des Nanostructures, INLN, UMR 5614, Université Nice Sophia Antipolis, CNRS, 06100 Nice, France
5 Laboratoire de Physique Corpusculaire, ESPCI Paris, UMR 7093, PSL University, 4 place Jussieu, 75252 Paris, France

LETTERS
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Andreev bound state in quantum dot

Andreev bound states in supercurrent-carrying carbon nanotubes revealed

J-D. Pillet¹, C. H. L. Quay¹†, P. Morfin², C. Bena³,⁴, A. Levy Yeyati⁵ and P. Joyez¹ *

1 Institut de Physique Théorique, Ecole Polytechnique, Palaiseau, France
2 Physique de la Matière Condensée, Institut Jean le Rond d’Alembert, UMR 7589, Université Pierre et Marie Curie, 4 place Jussieu, 75252 Paris, France
3 Laboratoire de Physique, Université de Savoie, F-73376 Le Bourget du Lac, France
4 Laboratoire des Nanostructures, INLN, UMR 5614, Université Nice Sophia Antipolis, CNRS, 06100 Nice, France
5 Laboratoire de Physique Corpusculaire, ESPCI Paris, UMR 7093, PSL University, 4 place Jussieu, 75252 Paris, France

LETTERS
PUBLISHED ONLINE: 14 NOVEMBER 2010 | DOI: 10.1038/NPHYS1811
Spin-resolved Andreev levels and parity crossings in hybrid superconductor–semiconductor nanostructures

Eduardo J. H. Lee¹, Xiaocheng Jiang², Manuel Houzet¹, Ramón Aguado³, Charles M. Lieber² and Silvano De Franceschi¹*

DOI: 10.1038/NNANO.2013.267
First-Order 0-π Quantum Phase Transition in the Kondo Regime of a Superconducting Carbon-Nanotube Quantum Dot

Romain Maurand,1 Tobias Meng,2 Edgar Bonet,1 Serge Florens,1 Laëtitia Marty,1,* and Wolfgang Wernsdorfer1

1Institut Néel, CNRS et Université Joseph Fourier, BP 166, F-38042 Grenoble Cedex 9, France
2Institut für Theoretische Physik, Universität zu Köln, Zülpicher Strasse 77, 50937 Köln, Germany
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The operating region of Fig. 1 changes sign strengthened when we have seen previously that Kondo correlations in JJ1 are. As shown in Sec. 2, (c) (f) transition in Kondo- and Coulomb-blockaded odd-charge states. Panels (a), (b), and (c) show, respectively, the stability of integer values, altering the superconducting state. For an Coulomb interaction on the dot [10, 2(a)], (e)

**FIG. 1.** Nano-SQUID characteristics. (a) Scanning-electron-microscopy image of the structure. (b) Normalized critical current for two parallel, uncoupled quantum dots in the Coulomb-blockade regime, with a weak crosstalk of about 4%. The shift (0 or 2) in the odd-occupancy region of JJ1 corresponding to the odd-occupancy of the first quantum dot. In the first case of a very strong Coulomb blockade, the even even odd is achieved by modifying the parity of the electronic charge of the microscopic parameters in the quantum dot. In the second case, the ground state can become a magnetic doublet. In this situation, dissipationless current reversal of the dissipationless current at zero temperature, a weak link opened up the way to a new class of nanostructures.

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Shiba state

Coherent long-range magnetic bound states in a superconductor

Gerbold C. Ménard, Sébastien Guissart, Christophe Brun, Stéphane Pons, Vasily S. Stolyarov, François Debontridder, Matthieu V. Leclerc, Etienne Janod, Laurent Cario, Dimitri Roditchev, Pascal Simon and Tristan Cren

Figure 3 | Spectral and spatial properties of an extended Yu-Shiba-Rusinov bound state in 2H-NbSe2. a, Experimental conductance map taken at −0.13 meV. The a and b lines indicate the crystallographic axes of 2H-NbSe2, whereas the a* and b* lines indicate the directions in the reciprocal space. b, Characteristic experimental spectra taken on top of the impurity (red), on the right branch, 4 nm from the centre of the impurity (green), and far from the impurity (blue). c, Spatial and energy evolution of the experimental tunnelling conductance spectra, dI/dV(x, V) along one branch of the star. The left side of the figure corresponds to the centre of the star and the right side to the top-right corner of the scanning area. The colour conductance scale is the same as that used in a. d, Conductance profiles of the electron- and hole-like YSR states as a function of the distance to the impurity along the same line as for c.