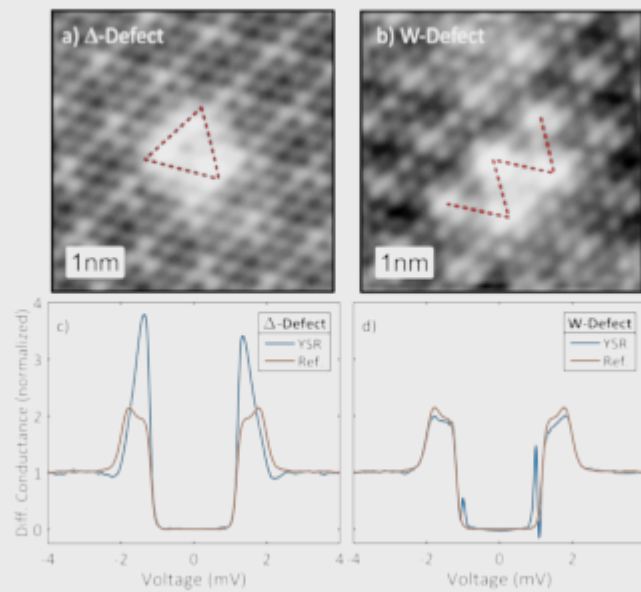


## Robustness of Yu-Shiba-Rusinov Resonances in Presence of a Complex Superconducting Order Parameter



Title: Robustness of Yu-Shiba-Rusinov Resonances in Presence of a Complex Superconducting Order Parameter.

When: Friday, May 04, (2018), 12:00.

Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).

Speaker: Christian R. Ast, Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany.

**R**obust quantum systems rely on having a protective environment with minimized relaxation channels. Superconducting gaps play an important role in the design of such environments. The interaction of localized single spins with a conventional superconductor generally leads to intrinsically extremely narrow Yu-Shiba-Rusinov (YSR) resonances protected inside the superconducting gap. However, this may not apply to superconductors with nontrivial, energy dependent order parameters. Exploiting the Fe-doped two-band superconductor NbSe<sub>2</sub>, we show that due to the nontrivial relation between its complex valued and energy dependent order parameters, YSR states are no longer restricted to be inside the gap. They can appear outside the gap (i.e. inside the coherence peaks), where they can also acquire a substantial intrinsic lifetime broadening. T-matrix scattering calculations show excellent agreement with the experimental data and relate the intrinsic YSR state broadening to the imaginary part of the host's order parameters. Our results suggest that non-thermal relaxation mechanisms contribute to the finite lifetime of the YSR states, even within the superconducting gap, making them less protected against residual interactions than previously assumed. YSR states may serve as valuable probes for nontrivial order

parameters promoting a judicious selection of protective superconductors.

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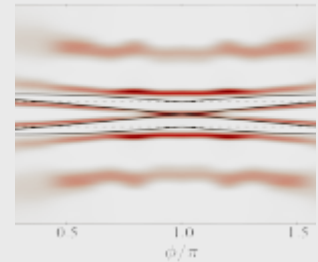
## Fractional Spin And Josephson Effect In Time-reversal-invariant Topological Superconductors

Title: Fractional Spin And Josephson Effect In Time-reversal-invariant Topological Superconductors.

When: Friday, February 17, (2017), 12:00.

Place: Departamento de Física Teórica de la Materia Condensada, Facultad Ciencias, Module 5, Seminar Room (5th Floor).

Speaker: Liliana Arrachea, International Center for Advanced Studies Universidad de San Martín, Argentina.

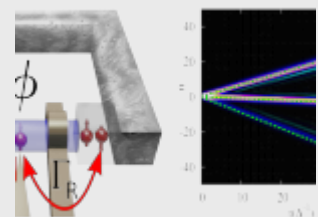


**T**ime reversal invariant topological superconducting (TRITOPS) wires are known to host a fractional spin  $\hbar/4$  at their ends. We investigate how this fractional spin affects the Josephson current in a TRITOPS-quantum dot-TRITOPS Josephson junction, describing the wire in a model which can be tuned between a topological and a nontopological phase. We compute the equilibrium Josephson current of the full model by continuous-time Monte Carlo simulations and interpret the results within an effective low-energy theory. We show that in the topological phase, the 0-to- $\pi$  transition is quenched via formation of a spin singlet from the quantum dot spin and the fractional spins associated with the two adjacent topological superconductors.

[More information on IFIMAC Website](#)

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## Quench Dynamics in Superconducting Nanojunctions: Formation of Andreev Bound States and Quasiparticle Trapping



Article: published in [Physical Review Letters](#) by R. Seoane Souto, [A. Martín-Rodero](#) and

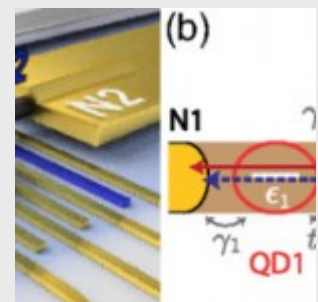
A. Levy Yeyati, Department of Theoretical Condensed Matter Physics and IFIMAC researchers.

**S**uperconducting junctions at the nanoscale are characterized by the presence of localized excitations lying within the superconducting energy gap, the so-called Andreev bound states. These states are sensitive to the superconducting phase jump through the junction and their population determines the supercurrent flowing through it. Nowadays experiments are allowing to analyze the population dynamics of these devices on very short time scales (below the microseconds), smaller than the typical relaxation times needed to approach the equilibrium conditions. In the present work we analyze the dynamics of quasiparticles in a superconducting nanojunction generated by a sudden quench of a given parameter like the phase or the voltage drop through it. We show that, for general conditions, the system gets trapped in a metastable state corresponding to a non-equilibrium population of the Andreev bound states. Our analysis, based on the so-called full counting statistics technique, reveals that the probability for trapping individual quasiparticles in the junction region can be as large as 50%, in agreement with recent experimental results. [\[Full article\]](#)

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### Quantum Interference in a Cooper Pair Splitter Makes Entanglement Production Plausible

Article: published in [Physical Review Letters](#) by Fernando Domínguez and [Alfredo Levy Yeyati](#), Department of Theoretical Condensed Matter Physics and IFIMAC researchers.



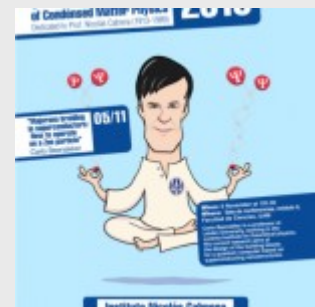
**I**n superconductors the electrons occur only in pairs, the so-called Cooper pairs. The electrons in these pairs are (spin) entangled, a quantum mechanical property that is at the heart of any prospective technology that exploits quantum mechanical effects. It was shown recently that these electrons can be separated into two parallel small islands, so-called quantum dots, through which only single electrons can pass at a time. This process is generally known as Cooper pair splitting. But are these electrons potentially useful? Or are the quantum correlations lost already on the dots due to

decoherence? Before the experiments and theoretical modeling by Fülöp et al., this question could be answered only by hand-waving arguments and it was not clear for what transport features one should look out. In the present article Fülöp et al. come one step closer to answering these questions: the authors demonstrate interference effects in a Cooper pair splitting device, a clear indication of (spatial) coherence. The use of Niobium as the superconductor allows the authors to tune electron levels not accessible for ordinary electrical gates, and to explain their data they introduce a conceptually new model of such a device. These results are relevant from a fundamental point of view, but also demonstrate the first Cooper pair splitting experiments at large magnetic fields. [\[Full article\]](#)

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## Majorana Braiding in Superconductors: How to Operate on a Zen Particle

### INC COLLOQUIUM - OFFICIAL ANNOUNCEMENT



Title: Majorana braiding in superconductors: How to operate on a Zen Particle

When: Tuesday 05 November, 2015 at 12h00

Where: Sala de conferencias módulo 00, Facultad de Ciencias.

Speaker: Carlo Beenakker, Lorentz Institute for Theoretical Physics, Leiden University, The Netherlands.

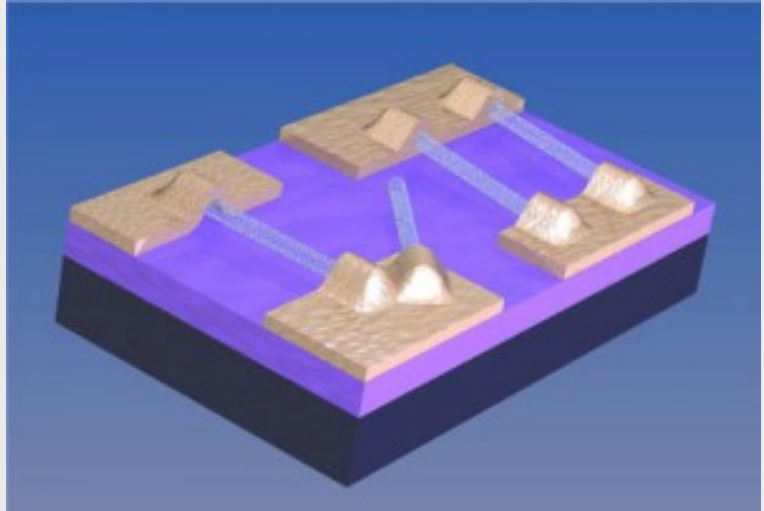
ABSTRACT:

**A**mong the many exotic properties of topological superconductors, the prediction that they can host Majoranas stands out both for its fundamental interest and for possible applications in topological quantum computing. To exchange (braid) pairs of Majoranas is the heroic experiment, since it would identify them as a fundamentally new type of quasiparticles with non-Abelian statistics. The road towards this goal has several milestones, starting from the detection of the zero-mode itself, on which the present generation of experiments is focused. In this talk we look ahead towards the next milestones: the construction of a qubit out of Majoranas, the measurement of its coherence times, and finally the braiding experiment to demonstrate its non-Abelian nature. The key problem that we address is how to operate on a cipher with zero charge, zero spin, zero energy, and zero mass — a “Zen particle”.

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## Superconductor Nanowire Superconductor Junctions as Useful Platforms to Study Topological Superconductivity and Majorana Bound States

*Date: Friday, 7th February 2014.*



*Time: 12:00h*

*Place: Departamento de Física de la Materia Condensada, Facultad Ciencias, Módulo 3 , Aula de Seminarios (5ª Planta).*

*Ramón Aguado (Instituto de Ciencia de Materiales de Madrid-CSIC).*

ABSTRACT:

**R**ecent experiments have reported conductance measurements in semiconducting nanowire-based systems that support the existence of Majorana bound states (MBS) at normal-superconductor (NS) junctions.

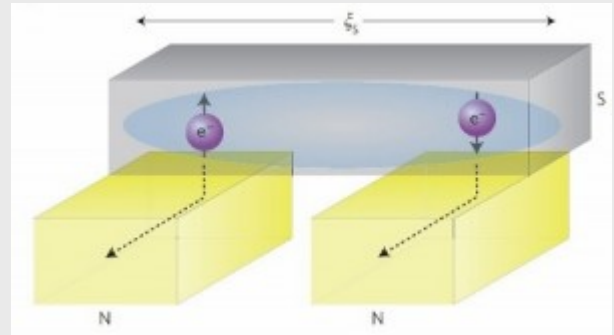
Although these experiments are partially consistent with the Majorana interpretation, other mechanisms such as disorder, Kondo physics, or Andreev bound states cannot be completely ruled out. It has thus become urgent to study alternative “smoking gun” measurement protocols. In this talk, I will argue that SNS junctions based on nanowires are extremely useful platforms to perform such alternative measurements.

Physical quantities that provide relevant information about MBS in such junctions include ac Josephson currents, multiple Andreev reflection (MAR) currents and supercurrents in multiband systems. Remarkably, the emergence and annihilation of MBS in multiband junctions is reflected in strong even-odd effects in the critical current  $I_c$  under specific conditions. This effect allows for a full mapping between  $I_c$  and the topological phase diagram of the junction.

[More information on IFIMAC Website](#)

## Cooper Pair Splitting as a Source of Entangled Electrons

Date: Monday, 16th December, 2013.



Time: 12:00h

Place: Departamento de Física Teórica de la Materia Condensada, Facultad Ciencias, Módulo 5 &, Aula de Seminarios (5ª Planta).

Jan Martinek (Institute of Molecular Physics- Polish Academy of Sciences).

ABSTRACT:

# W

e study an entangled state of spatially separated electrons, in particular its spins, in a solid state electronic system. The ground state of conventional superconductors is a singlet state of electron Cooper pairs that can provide a natural source of entangled electrons.

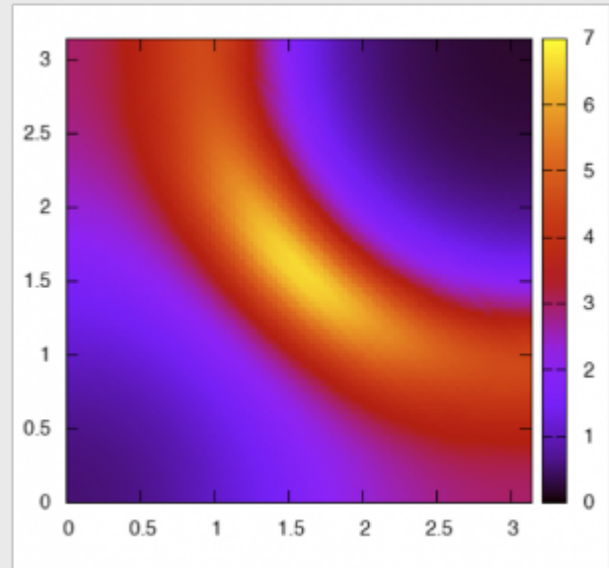
One of the proposals to obtain the nonlocal entanglement of electrons is to use the Cooper pairs split in the Double Quantum Dot (DQD) system using the Coulomb interaction between electrons. We have analyzed an efficiency of the separation of Cooper pairs in systems, where the DQD is connected to the two superconducting leads, or to the superconducting and normal leads. Addressing the idea of quantum communication with entangled electrons in a solid state, where ferromagnetic detectors allow for spin correlation detection, we provide, using quantum information theory, a lower bound on the spin polarization of detectors. In ferromagnetic detectors the spin information is transformed into charge information, however, any real magnetic materials feature imperfect spin polarization due to presence of both spin component in density of states at the Fermi surface. We find that lower bound for the spin polarization is  $p > 58\%$  for detection of entanglement using an optimal entanglement witness. It provides the minimal spin polarization of ferromagnetic materials that can be useful in quantum communication.

[More information on IFIMAC Website](#)

## Towards a microscopic description of the pseudogap phase in cuprate and organic superconductors

Wednesday, 11th January 2012. 12:00-13:00

*Jaime Merino*



Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid

### ABSTRACT:

Understanding the mechanism of high- $T_c$  superconductivity in cuprate materials is a fundamental challenge in condensed matter theory. The 'normal' metallic phase of these systems is highly unconventional displaying strong deviations from Landau-Fermi liquid behavior particularly in the underdoped regime in which a pseudogap phase with no apparent broken symmetry occurs. The most 'anomalous' observation in this phase is that the Fermi surface consists of disconnected arcs along the Brillouin zone diagonals violating the Luttinger sum rule condition. A pseudogap phase has also been observed in the metallic phase of layered organic materials which are in close proximity to a Mott insulating phase. The common existence of a pseudogap state in the doping driven Mott insulators (cuprates) and in the bandwidth Mott transition (organics) suggests that the pseudogap is inherent to properties of the Mott insulator in two-dimensional systems.

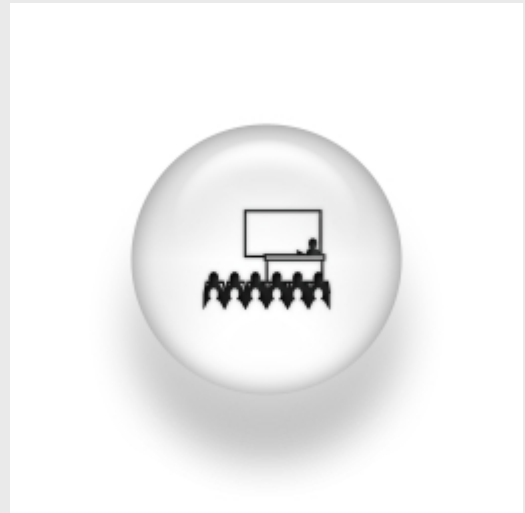
In order to understand the microscopic origin of the pseudogap phase we have explored the evolution of the one-electron properties across the Mott metal-insulator transition based on a single-band half-filled Hubbard model on a two-dimensional square lattice. As the Coulomb repulsion is increased electrons along the antinodal direction of the Brillouin zone open a gap (pseudogap) in the spectral density whereas electrons along the nodal direction display a quasiparticle-like peak. Since the pseudogap phase is found in the paramagnetic solution of the Hubbard model no broken symmetry occurs suggesting that is associated with short range electronic correlations. The nature of the excitations in the pseudogap phase is unveiled by analyzing pairing and

antiferromagnetic correlations. We find that  $dx^2-y^2$ -wave pairing correlations are enhanced whereas antiferromagnetism is suppressed within the pseudogap phase. This behavior is consistent with the resonant valence bond (RVB) wavefunction for the ground state proposed by Anderson and coworkers for the cuprate superconductors.

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## Which is the origin of the resistivity anisotropy in iron superconductors?

Wednesday, 16 February 2011, 12:00-13.00



*Prof. Leni Bascones*

Instituto de Ciencia de Materiales de Madrid, CSIC

### ABSTRACT:

The study of strongly correlated materials is one of the most active areas of materials science and continuously offers new surprises to the scientific community. The diversity of phases found in these systems is extremely rich. They show superconductivity, magnetism and nematicity among other states. Very often these phases compete. The discovery in 2008 of high- $T_c$  superconductivity in iron materials, is the latest major discovery in the field and initiates a new era in the study of superconductivity.

In these materials superconductivity appears when doping an anisotropic and metallic magnetic state. The origin of superconductivity in these materials remains unknown. On spite of some similarities in the phase diagram, metallicity in the magnetic state and multi-orbital character make these materials essentially different from the cuprates, the other high-temperature superconductors known. In the first part of the talk I will review the main properties and open questions which appear when studying these materials [1]. I will emphasize how important it is to understand the interplay between magnetic, orbital and structural degrees of freedom.

Later I will concentrate on recent experiments which have uncovered a large in-plane resistivity anisotropy with a surprising result: the system conducts better in the antiferromagnetic  $x$  direction than in the ferromagnetic  $y$  direction [2]. This result has



been interpreted by several authors in terms of a nematic state and orbital ordering. We address this problem by calculating the ratio of the Drude weight along the x and y directions in the magnetic state [3]. Our results points against orbital ordering as the origin of the observed conductivity anisotropy, which may be ascribed to the anisotropy of the Fermi velocity [4].

[1] For a recent review see Paglione and Green, *Nature Physics* 6, 645 (2010)

[2] Chu et al, *Science* 329, 824 (2010)

[3] E. Bascones, M.J. Calderón and B. Valenzuela, *PRL*.104, 227201 (2010)

[4] B. Valenzuela, E. Bascones and M.J. Calderón, *PRL* 105, 207202 (2010)

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