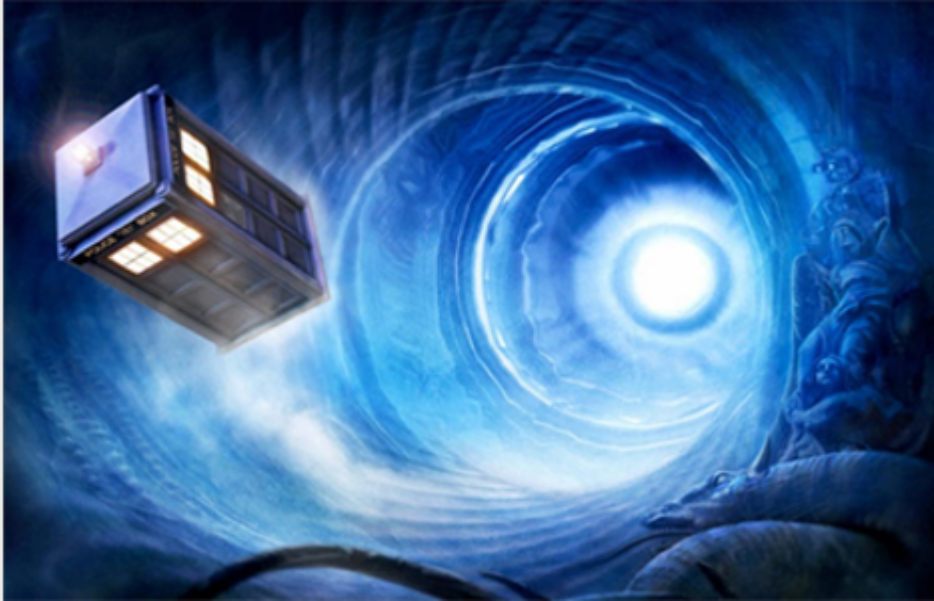


## Superconductors and Quantum Information Preservation in Black Holes



Title: Superconductors and Quantum Information Preservation in Black Holes.

When: Tuesday, January 30, (2018), 12:00.

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

Speaker: Andrew N. Jordan, Department of Physics and Astronomy, University of Rochester, New York, USA.

**T**his talk will demonstrate how the quantum information entering black holes is analogous to quantum information entering a superconductor. The analogy maps the interior of a black hole to a superconductor, and the exterior of the black hole to a normal metal. We show that the metal-superconductor interface can be thought of as an event horizon: The proximity effect in superconductor-metal interfaces (where Cooper pairs tend to form in the normal metal) is analogous to electron-positron creation at the event horizon in black-holes, which gives rise to Hawking radiation. Existing ideas of preserving quantum information entering black holes - the Preskill informational mirror, and the Horowitz-Maldacena mechanism for black-hole evaporation (which necessitates a unique final state for the black-hole), can be exactly realized as quantum information swapping or transfer using Andreev reflection processes. I will present mesoscopic physics analogs to wormholes with crossed Andreev reflection - and conjecture that the BCS ground state also describes the final quantum state of a black hole.

### References

Andreev reflections and the quantum physics of black holes, Sreenath K. Manikandan and Andrew N. Jordan, Phys. Rev. D 96, 124011, (2017).

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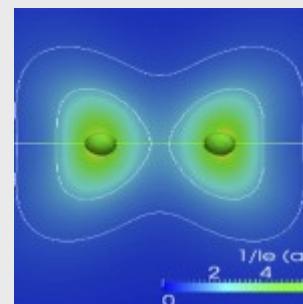
## Spin States in Molecules from a Quantum Information Perspective

Title: Spin States in Molecules from a Quantum Information Perspective

When: Thursday, 11 February (2016), 12:00h

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

Speaker: Filippo Troiani, S3 Instituto Nanoscience (CNR), Modena, Italy.



**M**olecular nanomagnets represent a playground for the controlled generation of highly nonclassical states [1]. In this talk, I will give an overview on the theoretical investigation of such states in terms of quantum-information theoretical quantities. As a representative example, I will discuss the case of spin clusters with dominant exchange interaction. Different forms of entanglement (bi- and multi-partite, between individual and collective spins) are shown to be present in ground state of these systems. These nonclassical features are detectable through experimentally accessible quantities (entanglement witnesses), and partially engineerable by means of available chemical substitutions [2]. Interestingly, spin entanglement can also be investigated in nonmagnetic atoms and molecules, within the framework of density-functional theory. In these systems, spin-pair entanglement decays with a characteristic length scale, which represents a sensitive indicator of the presence of atomic shells and molecular covalent bonds [3]. Time permitting, I will mention additional investigations of spin states in molecules from a quantum-information perspective. These include the quantitative characterization of Schrödinger-cat states [4] and the design of optimal parameter estimation processes within the framework of quantum estimation theory [5].

### References

F. Troiani and M. Affronte, *Chem. Soc. Rev.* 40, 3119 (2011).

See, e.g., F. Troiani and I. Siloi, *Phys. Rev. A* 90, 042328 (2014).

S. Pittalis, F. Troiani, C.A. Rozzi, and G. Vignale, *Phys. Rev. B* 91, 075109 (2015).

F. Troiani and P. Zanardi, *Phys. Rev. B* 88, 094413 (2014).

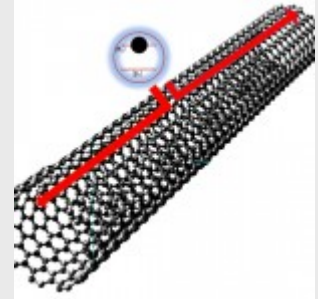
F. Troiani and M.G.A. Paris (in preparation).

[More information on IFIMAC Website](#)

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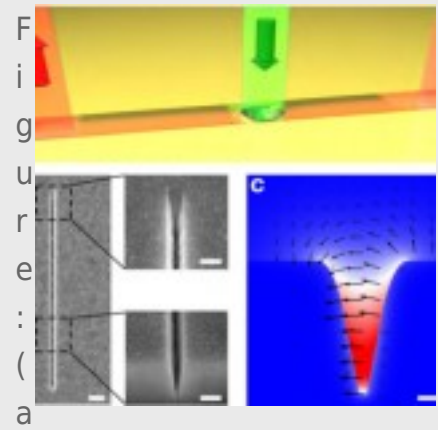
## Ultraefficient Coupling of a Quantum Emitter to the Tunable Guided Plasmons of a Carbon Nanotube

Article: published in [Physical Review Letters](#) by Francisco J. García-Vidal, Department of Theoretical Condensed Matter Physics and IFIMAC researcher.



**T**he quest for schemes leading to efficient coupling between quantum emitters and the electromagnetic field is very actively pursued nowadays, for its potential applications to quantum information and to induce effective interactions between two-level systems (mediated by the electromagnetic field) and effective photon-photon interactions (mediated by the quantum emitters).

In this context, IFIMAC researcher Francisco J. Garcia-Vidal, in collaboration with Luis Martin-Moreno (ICMA) and Javier Garcia de Abajo (ICFO) have shown that the tunable plasmons of a highly doped single-wall carbon nanotube are a very promising platform for efficient coupling between quantum emitters and the confined plasmon field. Plasmons in these quasi-one-dimensional carbon structures exhibit very deep subwavelength confinement that pushes the coupling efficiency close to 100% over a very broad spectral range. This phenomenon takes place for distances and tube diameters comprising the nanometer and micrometer scales. As opposite to other metallic systems and also to graphene, carbon nanotubes present the crucial advantage of not requiring a spacer to avoid quenching (i.e., irreversible dissipation leading to heating of the metal) of quantum emitters at small separations. This finding not only holds great potential for waveguide Quantum Electrodynamics, in which an efficient interaction between emitters and electromagnetic modes is pivotal, but it also provides a way of realizing quantum strong coupling between several emitters mediated by carbon nanotube plasmons, which can be controlled through the large electro-optical tunability of these excitations. [\[Full article\]](#)



(a) Schematic of the considered configuration. A single nanodiamond hosting a single nitrogen vacancy (NV) center is placed inside a V-groove channel waveguide. On excitation with a laser, the NV center couples, in the ideal case, all of its emission into the VG-supported CPP mode. The channeled emission out-couples from the VG via the tapered nanomirrors at the VG extremities. (b) Scanning electron microscopy (SEM) image of a 10- $\mu\text{m}$ -long V-shaped groove (B315-nm-width and B510-nm-depth) fabricated by milling a thick gold film with a FIB. The scale bar is 1  $\mu\text{m}$ . (c) Total electric field profile of the VG-supported CPP mode for a wavelength of 650 nm.

Article: published in [Nature Communications](#) by Carlos González Ballester, [Esteban Moreno](#) and [Prof. Francisco J. García Vidal](#), Department of Theoretical Condensed Matter Physics and IFIMAC researchers.

Department of Theoretical Condensed Matter Physics and [IFIMAC - Condensed Matter Physics Center](#) researchers report on deterministic coupling of single quantum emitters with channel plasmons

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ne of the main challenges in developing future nanoscale quantum photonic circuits is to manage combining on a single chip a single photon source, waveguides, modulators and detectors. An important milestone towards this ultimate goal is the deterministic coupling of a single quantum emitter to an integrated waveguide. In this context, IFIMAC researchers Carlos González Ballesterero and Esteban Moreno lead by Prof. Francisco J. García Vidal, in collaboration with scientists from ICFO in Barcelona (Romain Quidant's group), Denmark (Sergey Bozhevolnyi's group) and United Kingdom (Yuri Alaverdyan), have been able to demonstrate coupling of the emission of a single quantum emitter to channel plasmons polaritons (CPPs) in a V-shaped plasmonic architecture. The study "Coupling of individual quantum emitters to channel plasmons", has been published recently in the journal Nature Communications.

In this work, the researchers first used theoretical simulations to study the behaviour of the coupling between a quantum emitter and the V-groove plasmonic channel. Once an optimal theoretical configuration was identified, they used state-of-the-art techniques to assemble the experiment using a single Nitrogen Vacancy (NV) centre, a single quantum emitter present in diamond, coupled to the CPPs supported by a V-groove (VG) channel. The observations obtained from the experiment revealed efficient coupling of the NV centre emission to the propagating modes of the VG, in accordance with the theoretical predictions postulated by the team. This demonstrates that their approach can enable realistic and functional plasmonic circuitry and therefore, paves the way towards the development of efficient and long distance transfer of energy in integrated solid-state quantum systems. [\[Full article\]](#)

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