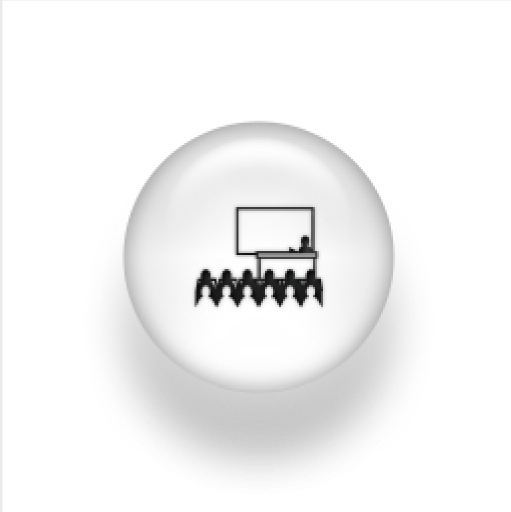
Ring-shaped nanomagnets: from quantum effects to spin-cluster qubits

Friday, 29 April 2011. 12:00-13.00



Prof. Filippo Troiani
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ABSTRACT:
Molecular nanomagnets represent a wide class of spin cluster, whose structural and magnetic properties can be widely engineered by chemical synthesis [1]. Historically, much attention has been devoted to high-spin molecules (the so-called *single-molecule magnets*) with anisotropy barriers, where the magnetic memory is ultimately limited by the quantum tunneling of magnetization. The present talk will be concerned with a different class of molecules, namely antiferromagnetic spin rings, that have recently attracted a widespread interest also in view of their possible use in quantum-information processing. In this perspective, three different aspects will be considered. Firstly, recent progress in the control on intermolecular coupling between ring-shaped nanomagnets will be discussed [2]. Such capability represent a first, crucial requirement on the way of growing a scalable hardware based on the nanomagnet as a building block, and has enabled the demonstration of (equilibrium-state) entanglement between pairs of rings [3]. Secondly, the electron-spin decoherence in single nanomagnets and coupled rings will be considered. In both cases, decoherence results from the dynamics of the nuclear bath, and specifically from the build-up of quantum correlations between electron and nuclear spins. Based on a microscopic model of the molecules, we show how the chemical elements and the physical processes that drive decoherence can drastically depend on the specific linear superposition of interest [4]: as an illustrative example, we compare the cases of singlet-triplet superpositions in ring dimers with that of the Bell states. The final part of the talk will be devoted to a novel approach to the use of antiferromagnetic spin rings in quantum information processing, based on the use of electric fields as a means for the manipulation of the quantum state [5]. Here, the computational degree of freedom is not the spin projection – as in most spin-based approaches – but spin chirality. Magnetically frustrated systems – such as homometallic odd-numbered rings – with antisymmetric exchange (Dzyaloshinskii-Moriya) interaction present ground-state multiplets with well defined chirality. The

general conditions for the existence of such spin-electric coupling in spin rings will be discussed, and preliminary results will be presented on hyperfine-induced decoherence of spin chirality.

References
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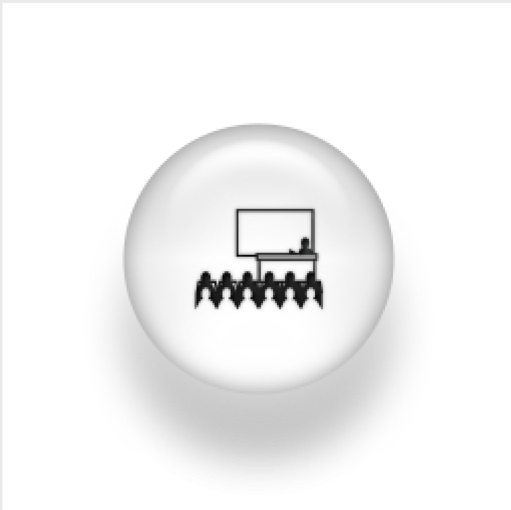
[2] G. Timco, S. Carretta, F. Troiani, F. Tuna, R. J. Pritchard *et al.*, Nat. Nanotechnol. 4, 173 (2009).
[3] A. Candini, G. Lorusso, F. Troiani , A. Ghirri, S. Carretta *et al.*, Phys. Rev. Lett. 104, 037203 (2010).
[4] A. Szallas and F. Troiani, Phys. Rev. B 82, 224409 (2010).
[5] M. Trif, F. Troiani, D. Stepanenko, and D. Loss, Phys. Rev. Lett. 101, 217201 (2008).

Towards quantum plasmonics: plasmon mediated qubit-qubit entanglement

Wednesday, 2 March 2011, 12:00-13.00



Alejandro González-Tudela
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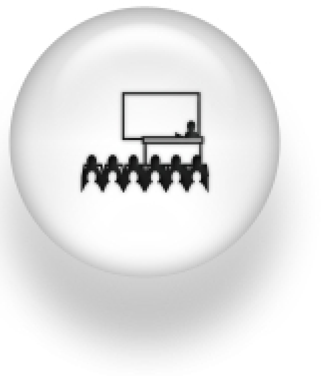
ABSTRACT:
The field of nanoplasmonics has received an extraordinary attention in the last few years due to the prediction of a lot of interesting physical phenomena such as extraordinary optical transmission, enhanced energy transfer, surface plasmon sensors and many more [1].
All these phenomena can be obtained from a classical description of the field, however there have been a few steps in exploring its quantum regime,i.e., generating single plasmons [2] using nanowires. Our way to quantum plasmonics started studying the dissipative dynamics of a single emitter close to a metal-semiconductor interface [3].
After the proposal of coupling two qubits through plasmonics one-dimensional nanowaveguides [4], we have studied the possibility of coupling two qubits by plasmons

supported by them. The plasmons induce coherent and incoherent coupling between the qubits, dephased π/2 between them, allowing us to switch off one of the two contributions while maximising the other by altering the interqubit distance. Mainly due to the dissipative component of this coupling we could find situations of spontaneous formation of entanglement and using a laser a stationary entangled state appears for distances larger than the operating wavelength [5].

[1] F.J Garcia-Vidal et al, Rev. Mod. Phys. 82, 729 (2010)
[2] A. Akimov et al. Nature 450, 402 (2007)
[3] A. Gonzalez-Tudela, Phys. Rev. B 82, 115334 (2010)
[4] D. Martín-Cano et al, Nano Lett. 10, 3129 (2010)
[5] A. Gonzalez-Tudela et al, Phys. Rev. Lett., 106, 020501 (2011). Highlighted in Physics.

Noise Correlations and Coherent Coupling in Solid State Qubits

Wednesday, 24 March 2010, 12:0013.00



Prof. David Marcos
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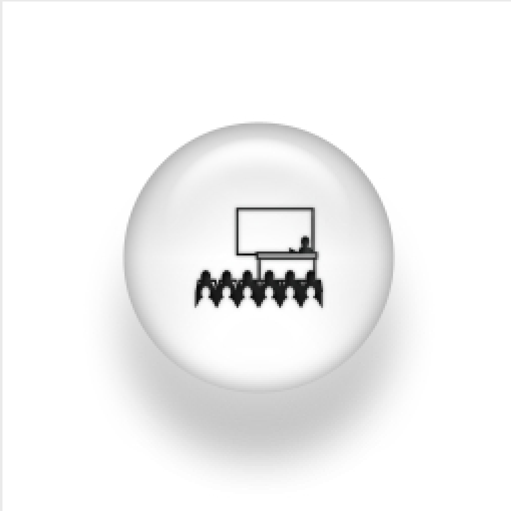
ABSTRACT:
In this seminar I will present recent advances in the fields of quantum transport and and hybrid quantum systems. The former has incorporated a theory of counting statistics to investigate high-order current correlations through nanoscopic conductors. These can reveal valuable information such as coherence times and phase transitions.
In particular, I will apply the theory to investigate the fluctuation- dissipation theorem in situations out of equilibrium and also show how a non-Markovian description becomes essential to study quantum noise. In the second part, I will review some proposals that combine solid- state and quantum-optics systems in the context of quantum information processing. I shall present a hybrid system consisting on a flux qubit coupled to an ensemble of NV centers in diamond. At high densities coherent

transfer between both systems becomes possible, and therefore this opens the possibility of interfacing superconducting qubits with light.

Quantum control of spin qubits in Silicon

Wednesday, 27 January 2010, 12:00-13.00



Dr. Maria Jose Calderon
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ABSTRACT:
Doped Si is a promising candidate for quantum computing [1] due to its scalability properties, long spin coherence times, and the astonishing progress on Si technology and miniaturization in the last few decades.
This proposal for a quantum computer ultimately relies on the quantum control of electrons bound to donors near a Si/barrier (e.g. SiO_2) interface. I will address several important issues and define critical parameters that establish the conditions that allow the manipulation of donor electrons in Si by means of external electric and magnetic fields [2-4]. In particular, I will discuss the effect of the conduction band degeneracy in Si on this manipulation [3] and how this degeneracy may be lifted at an interface with an insulator [5].

[1] B. Kane, Nature 393, 133 (1998)
[2] M.J. Calderón, B. Koiller, X. Hu and S. Das Sarma, Phys. Rev. Lett. 96, 096802 (2006).
[3] M.J. Calderón, B. Koiller, and S. Das Sarma, Phys. Rev. B 77, 155302 (2008).
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