BOOK OF ABSTRACTS

i-link network: Quantum fluctuations and dissipation: towards highly efficient and precise nano engines

First i-link Workshop: Novel trends topological systems and quantum thermodynamics

Convocatoria I-LINKB2021 con referencia LINKB20072

Organized by
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Neutral excitations produced on-demand in the Fermi sea (Injection from a driven Andreev's level)

Misha Moskalets

June 5th, 10:00 (45') **(Keynote)**

I discuss single-particle injection from the Andreev level and how such injection is simulated using a voltage pulse. Recently, high-speed quantum-coherent electron sources injecting one- to few-particle excitations into the Fermi sea have been experimentally realized. The main obstacle to using these excitations as flying qubits for quantum-information processing purposes is decoherence due to the long-range Coulomb interaction. An obvious way to get around this difficulty is to employ electrically neutral excitations. Here I discuss how such excitations can be generated on-demand using the same injection principles as in existing electron sources. Namely, with the help of a voltage pulse of a certain shape applied to the Fermi sea, or using a driven quantum dot with superconducting correlations. The advantage of the latter approach is the possibility to vary the electron-hole content in the excitation.

Topological metal arising from strongly disordered Floquet operators

Kun Woo Kim

June 5th, 10:45 (30´)

A time evolution of quantum mechanical states by a time periodic Hamiltonian may contain extra information of topology in the time domain. As a result, there are examples of topological Floquet matter that are distinct from static counterparts. In this talk, I would like to introduce a time evolution operator that simulates the low energy physics of topological metal. The evolution comes with strong disorder mixing information in the quasi-energy domain. I will provide concrete numerical evidence testing the topological metallicity and simple experimental proposals identifying them.

Coupling between two quantum dots through a superconducting island

Adam Bacsi

June 5th, 11:45 (30´)

Superconducting quantum devices have attracted growing interest in the last several years due to their potential applications in quantum computation. The combination of quantum dots and superconducting islands is considered as possible qubit realization. I present a theoretical model describing two quantum dots coupled to a superconducting island and focus on the regime when both dots host a single particle and, hence, carry a magnetic moment. Whether the spins are ferromagnetically or antiferromagnetically aligned, depends strongly on the competition of several energy scales. I will show that in the flatband limit, i.e., when the bandwidth of the bulk superconductor is negligibly small, the spins form a singlet in the ground state. However, if the bandwidth is increased over a critical value, the spin alignment becomes ferromagnetic. The results also imply that the flatband limit cannot be applied to the whole regime of this kind of superconducting qubit systems.

CTopological Superconductivity and Majorana Modes in Magnetic Topological Insulators

Daniele di Miceli

June 5th, 12:15 (30´)

Magnetic topological insulators (MTIs), i.e., three-dimensional topological insulators with surface states and ferromagnetic ordering, are a fundamental class of new materials which can be exploited to realize several different insulating phases. In addition, through proximity to an ordinary s-wave superconductor, they can be used to achieve topological superconductivity, hosting topologically-protected Majorana modes over the edges. In this talk, we review these different superconducting states and discuss their properties in terms of bulk topological invariants and corresponding boundary modes. While thin films of proximitized MTIs can realize the so-called "chiral" topological superconductor (TSC), characterized by dispersive Majorana modes propagating on the edges [1], narrow MTI ribbons can realize effective 1D TSC with Majorana bound states localized on the ends [2, 3]. In the last part of the talk, we discuss the electric signals associated to the emergence of such Majorana quasiparticles in a NSN junction between normal (N) and proximitized (S) MTI slabs. We focus on the specific case of an asymmetrically split bias between the two normal leads, and discuss the different behaviours which can be associated to these different types of Majorana states [4].

References

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Light-matter correlations in Quantum Floquet Engineering

Beatriz Pérez

June 5th, 12:45 (30´)

Quantum Floquet engineering requires a proper gauge-invariant description of light-matter interaction to correctly capture the physics of the system beyond the strong-coupling regime. This means that such models typically involve a highly non-linear dependence on the photonic operators which makes their analysis and simulation complex. In this work, we provide a non-perturbative truncation scheme for the light-matter Hamiltonian, which is valid for arbitrary coupling strength. Within this framework, we investigate the crucial role of light-matter correlations, which are absent in a classical Floquet description. We find that, even in the high-frequency regime, they can spontaneously break key symmetries for topological protection, and be detected in the photonic spectral function. We exemplify our findings with the SSH chain, and show that a topological phase transition can be induced by coupling to a cavity and that the critical point can be predicted from the spectral function.

Long range quantum transfer through semiconductor quantum dot arrays

Gloria Platero

June 5th, 14:45 (45´) **(Keynote)**

The fabrication and control of long semiconductor quantum dot arrays open the possibility to use these systems as quantum links, for transferring quantum information between distant sites, an indispensable part of large-scale quantum information processing. Great effort is currently being devoted to the investigation of hole spin qubits in quantum dots owing to their long coherence time resulting from the weak hyperfine coupling to nuclear spins and rapid operation time due to the inherently strong spin–orbit coupling (SOC) [1]. In this talk I will discuss different pulse-based protocols, both adiabatic and those based on shortcuts to adiabaticity, to transfer spin holes between edges of a quantum dot chain with high fidelity. I will show how the spin polarization of the transferred holes can be controlled by tuning the ratio between the SOC and the spin conserving tunneling rate [2]. Also, I will discuss how to transfer entangled hole spin qubits between edge dots. Our theoretical results suggest the feasibility of quantum dot arrays as high-fidelity quantum buses to distribute information between distant sites and perform one qubit gates in parallel. An alternative way to transfer information between distant sites, is to use protected topological edge states in systems with non-trivial topology. It has been shown that applying an AC-driving protocol, it is possible to induce topological edge states in quantum dot arrays [3]. I will discuss the long-range particle dynamics mediated by edge states in different quantum dot array configurations [4], which can be experimentally detected with QDs charge detectors, and which opens a new avenue for quantum state transfer protocols in low dimensional topological lattices.

References

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Coherence for quantum-enhanced thermodynamic performance in steady-state quantum thermal machines

José Antonio Almanza

June 5th, 15:15 (30´)

Quantum coherence has been shown to impact the operational capabilities of quantum systems performing thermodynamic tasks in a significant way, and yet the possibility of genuine coherence-enhanced thermodynamic operation remains unclear. Here we show that only the presence of energetic coherence —coherence between levels with different energies— in steady-state quantum thermal machines can lead to genuine thermodynamic advantage. On the other hand, engines showing coherence between degenerate levels, or subjected to noise-induced coherence, are shown to be systematically emulated by classical stochastic engines using exactly the same set of (incoherent) resources. We illustrate our results with three famous models of heat engines and refrigerators and employ multi-objective optimization techniques to characterize quantum-enhanced regimes in connection with the thermodynamic uncertainty relation.

Photo-assisted spin transport in double quantum dots with spin-orbit interaction

David Fernández

June 5th, 15:45 (30´)

Spin qubits in semiconductor quantum dots (QDs) have emerged as a promising platform for scalable and high-fidelity quantum computing. These qubits encode information in the particle's spin state, which can be manipulated using electrical pulses. To maximize the potential of this platform, a thorough understanding of the underlying processes is required, including the effects of spin-orbit coupling (SOC) that lead to spin rotations and novel spin transport features.

This talk focuses on a double quantum dot (DQD) system under an AC electric field and strong SOC. We explore the interplay between SOC-induced spin-flip tunneling and electric-dipole spin resonances caused by the AC field, which can result in current suppression due to a dark state (DS) formation. We demonstrate the use of DSs for characterizing the SOC in the system, and for storing quantum information. We also show that the spin qubit dynamics can be fully controlled by tuning the driving pulse. Additionally, we obtain highly polarized spin currents through the DQD, even in the presence of weak SOC. Finally, we explore the implementation of a flopping-mode qubit, where an effective magnetic field in the x-direction emerges from virtual transitions to the other QD. The present configuration allows for full control of quantum gates applied to the qubit by adjusting the parameters of the applied pulse.

Unraveling heat and charge transport in time-periodic temperature driven interacting nanoconductors

Minchul Lee

June 6th, 9:30 (45´) **(Keynote)**

We investigate the time thermal transport of charge and heat through a quantum conductor coupled to metallic contacts. We consider that the conductor is driven by time-dependent temperatures applied to each contact. Such situation is theoretically implemented by applying the concept of gravitational field firstly introduced by Luttinger in the sixties. The gravitational field plays a similar role as the electrostatic potential that enters in the Hamiltonian to describe Coulomb interaction between charges. The new field enters in the Hamiltonian coupled to the energy of each contact. Within a tight-biding description for the Hamiltonian the contact energy has been defined considering the energy stored in the tunneling barriers in order to satisfy the Onsager reciprocity relations. Here, we present our considerations about the validity of the Luttinger trick for the time-dependent transport and the possible pathologies when it is applied in the calculation for the heat flow. To made analytical progress we treat the linear response regime and derive an equivalent quantum RC circuit for the thermoelectrical and thermal conductances.

Topological states in bilayer graphene systems

Llorenç Serra
June 6th, 10:15

I will discuss the physics of topological states in bilayer graphene nanostructures defined with electrostatic gates. Particularly, I will focus on the so-called kink states appearing at the borders of interlayer field inversions, and the edge states at the gapped-ungapped borders induced with electrostatic gates. These topological states are characterized by valley-momentum locking, with reversed valleys propagating in opposite directions along the edge. We will also discuss the manifestation of such states in transport measurements with different types of junctions in bilayer graphene.

References

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Quantum memories for squeezed and coherent superpositions in a driven-dissipative non-linear oscillator

Adriàn Labay

June 6th, 10:45 (30´)

We propose a realization of associative memory with a single driven-dissipative quantum oscillator exploiting its infinite degrees of freedom in phase space. First of all, the model can improve the storage capacity of discrete neuron-based systems in a large regime and we prove successful state discrimination between n coherent states, which represent the stored patterns of the system [1]. We also present a generalization of these oscillators, which are not limited to coherent states. Specifically, we investigate the storage of squeezed states in the presence of different driving and dissipative degrees. Additionally, we demonstrate that coherent superpositions of squeezed states are achievable in the presence of a strong symmetry, thereby allowing for the storage of squeezed cat-states. Finally, we investigate the potential application of these nonlinear driven-dissipative resonators for quantum computing, analyzing the impact of squeezing on their performance.

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Impurity Knight shift in quantum dot Josephson junctions

Rok Zitko

6th June, 11:45

Josephson junctions with an embedded quantum dot are an implementation of Andreev spin qubits that carry two quantum degrees of freedom: the spin on the quantum dot and the two-level system formed by the superconducting condensate. Both degrees of freedom can be probed and coherently manipulated. Such devices can be modelled using the Anderson impurity model with superconducting leads. I will present recent results on the properties of the sub-gap states in all parameter regimes, including for strong coupling (hybridisation). I will focus on the quantity which quantifies the degree of Kondo screening of the impurity local moment and at the same time characterizes the renormalization of the Zeeman splitting (impurity Knight shift). It turns out that this quantity depends on the superconducting phase difference across the junction, which implies the existence of a magnetic-field tunable coupling between the impurity spin and the superconducting circuit degrees of freedom.

References

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Quantum-enhanced performance in superconducting Andreev-reflection engines

Gonzalo Manzano

6th June, 12:15 (30')

When a quantum dot is attached to a metallic reservoir and a superconducting contact Andreev processes leads to a finite subgap current at the normal lead and the creation or destruction of Cooper pairs. In this talk I will introduce Andreev-reflection engines, that profit from the destruction of Cooper pairs to provide the work needed to set a charge current at the normal-conductor contact generating electrical power. For this power-transduction device high power and large efficiencies in quantum-mechanically enhanced regimes can be attained. Moreover thermodynamic trade-off relations between power, efficiency and stability, valid for any classical engine are overcome, and kinetic constraints on the engine precision are largely surpassed in arbitrary far from equilibrium conditions. These violations demonstrate a quantum-mechanical advantage of these engines in comparison with their classical counterparts.

Proposal for Detection of the $0'$ and π' Phases in Quantum-Dot Josephson Junctions

Rosa López

6th June, 12:45 (30')

The competition between the Kondo correlation and superconductivity in quantum-dot Josephson junctions (QDJJs) has been known to drive a quantum phase transition between 0 and π junctions. Theoretical studies so far have predicted that under strong Coulomb correlations the $0 - \pi$ transition should go through intermediate states, $0'$ and π' phases. By combining a nonperturbative numerical method and the resistively shunted junction model, we investigated the magnetic-field-driven phase transition of the QDJJs in the Kondo regime and found that the low-field magnetotransport exhibits a unique feature which can be used to distinguish the intermediate phases. In particular, the magnetic-field driven $\pi' - \pi$ transition is found to lead to the enhancement of the supercurrent which is strongly related to the Kondo effect.

Quantum state geometry in electronic platforms

Diego Frustaglia
6th June, 14:45 **(Keynote)**

We review three ongoing research lines in our group by discussing some published as well as preliminary results: (i) geometric resources for spin-carrier manipulation, (ii) simulation of non-Euclidean spaces in metric quantum networks, and (iii) electron quantum optics for quantum contextuality.

Fast quantum transfer mediated by topological domain walls

Juan Zurita

6th June, 15:30

In recent years, the number of proposed quantum protocols which use the protected end states of topological insulators has increased steadily [1, 2, 3, 4]. One of the challenges that most of these protocols face, especially in the case of bidirectional transfers, is the exponential scaling of their duration with transfer distance. This increases the number of errors and makes the protocols impractical for long-range transmission of information.

We propose a simple way to eliminate this exponential dependence: the use of topological domain walls as quantum amplifiers, which can exponentially enhance the effective hopping amplitude between the two end states, making the protocols much faster and more robust against all kinds of noise [5].

We apply this principle to the simplest topological insulator, the SSH chain, in which domain walls are induced by simply changing the hopping amplitude dimerization. This makes these systems as easy to build as their single-domain counterparts, and could thus be realized in the variety of platforms in which the SSH chain has been implemented, including photonic lattices or cold atoms.

Additionally, we also studied the previously unexplored domain walls in another topological model, the Creutz ladder, which features completely flat bands. It has attracted a great deal of attention since its first experimental realizations in the last four years [6, 7, **?**]. The domain walls in this model can hold up to two topological states, one of which can be used as a quantum memory while the other transfers information through the wall. This allows for arbitrarily complex transfer operations between topological states. We discuss how to implement this complex model using state-of-the-art technology. Finally, we will discuss the possible applications of these protocols in quantum computation and communication.

References

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