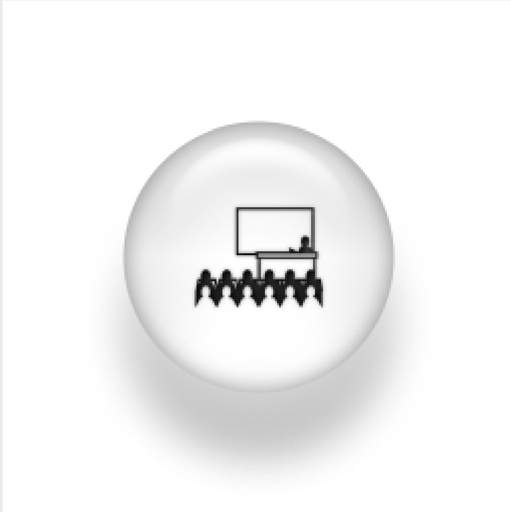
Quantum Optics as Tools to Probe the Spacetime Structure

Tuesday, 10th November 2011. 15:00-16:00



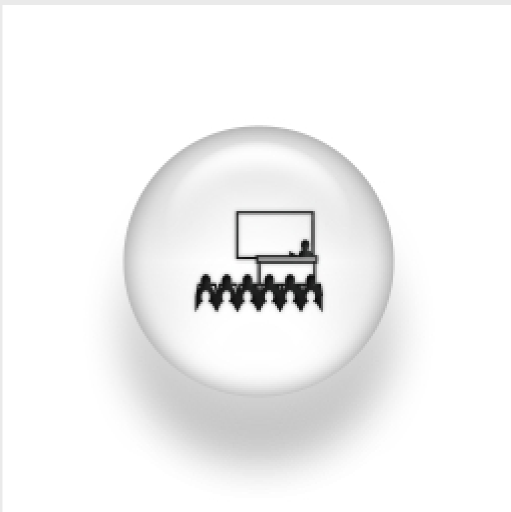
Eduardo Martín Martínez

CSIC

ABSTRACT:
Relativistic quantum information theory uses well-known tools coming from quantum information and quantum optics to study quantum effects provoked by gravity and to learn information about the spacetime. One can take advantage of our knowledge about quantum optics and quantum information theory to analyse from a new perspective the effects produced by the gravitational interaction. I will present some results and new ideas in this topic: two experimental proposals for the detection of the Unruh and Hawking effects and a quantum simulation of general relativistic settings.

The impact of electron interactions on one-dimensional helical conductors and Majorana end states

Wednesday, 2nd noviembre 2011. 12:00-13:00

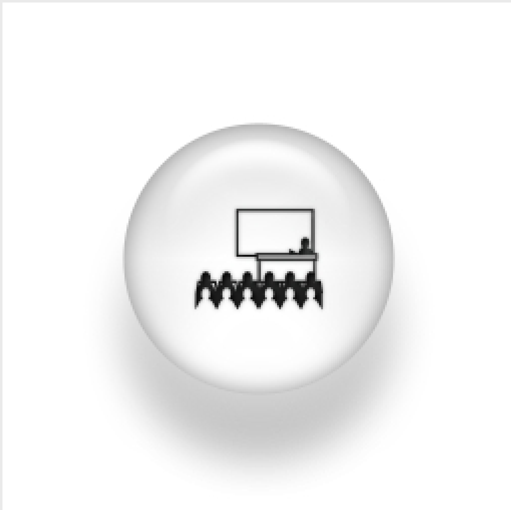


Bernd Braunecker
Dpto. Física Teórica de la Materia Condensada, UAM

ABSTRACT:
Majorana bound states appear at the ends of one-dimensional helical (i.e., spin-filtered) conductors if they are brought in the proximity of a superconductor. Such Majorana states have received much attention very recently due to their potential usefulness for topological quantum computation, quantum memories, or Cooper-pair splitters.
In my talk, I will discuss the effect of electron-electron interactions on the helical conductors (in the normal and superconducting state) and on the Majorana end states. I will show that already in the normal state the different helical conductors that are usually considered as equivalent exhibit substantial differences if electron interactions are taken into account [1]. Furthermore, I will show that the superconducting state is extremely susceptible to electron interactions [2]. Strong interactions generically destroy the induced superconducting gap that stabilizes the Majorana end states. On the other hand, for weak interactions the interaction-induced renormalization of the gap is nonuniversal and allows for a regime in which the Majorana edge states persist. I will discuss strategies how this regime can be reached and outline the consequences for experiments.
[1] B. Braunecker, C. Bena, and P. Simon, arXiv:1110.5171.
[2] S. Gangadharaiah, B. Braunecker, P. Simon, and D. Loss, Phys. Rev. Lett. 107, 036801 (2011).

Landau-Zener tunneling of qubits: dynamics, decoherence, and measurement

Wednesday, 26th octubre 2011. 12:00-13:00

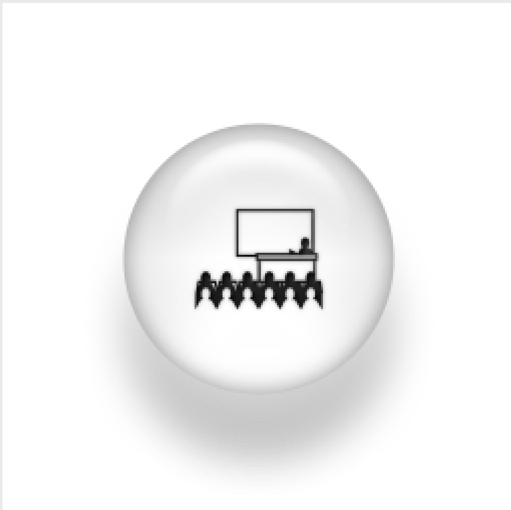


Sigmund Kohler
Instituto de Ciencia de Materiales de Madrid, CSIC
ABSTRACT:
The spectrum of a quantum system as function of a control parameter generically exhibits anti-crossings. A classic example is the electronic spectrum of two colliding molecules within Born-Oppenheimer approximation. How probable are then electronic

excitations due to the collision? Or in turn, how likely is it that the electrons follow adiabatically their ground state? Landau, Zener, Stuckelberg, and Majorana already in 1932 independently answered this question for an idealized two-level model. Their scenario possesses many modern applications, also in quantum information, where the anti-crossing can be used as effective beam splitter allowing state preparation. The coupling to an environment entails quantum dissipation and decoherence to the resulting superposition. Then the known Landau-Zener formula needs to be generalized to the presence of external degrees of freedom. It turns out that at zero temperature, this problem possesses an exact solution. Applications range from single-photon generation in circuit-QED to adiabatic quantum computing and the measurement of tunnel splittings in molecular nanomagnets. Finally, I will address the question whether the dynamics of the transition can be observed in an experiment.

A new tool for particle hydrodynamics at different scales

Wednesday, 19th October 2011. 12:00-13:00



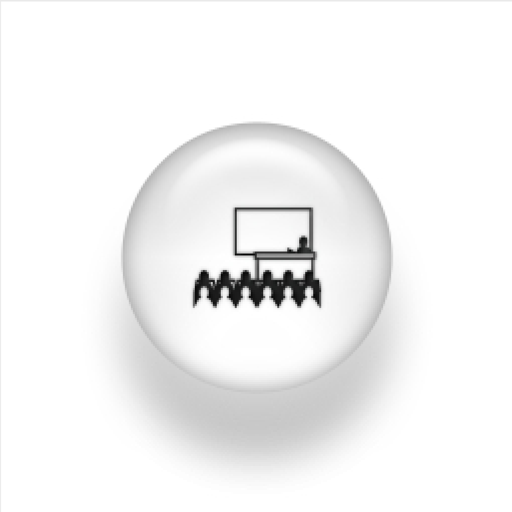
Rafael Delgado Buscalioni
Departamento de Física Teórica de la Materia Condensada, Universidad Autónom de Madrid

ABSTRACT:
In this informal talk I will present a new algorithm for particle hydrodynamics recently developed in the Dept. Fisica Teorica de la Materia Condensada (UAM). It is ideally suited to solve colloidal or polymeric suspensions at small Reynolds or even dispersions of larger particles in turbulent flow. The general framework consists on solving the solvent (fluctuating) hydrodynamics in an Eulerian mesh, while the solute Lagrangian dynamics are solved in continuum space. The scheme is quite general, also allowing for fluid-structure interactions, however I will focus on the so called “pointparticle” representation, where each particle is determined by an effective volume and the dynamics of its center of mass translation (rotation can also be added). In these kind of

schemes, the force between particle and fluid have been usually assumed to be frictional and of the same form of the Stokes drag. However, such approximation limits the applicability of the method to times larger than the friction response (i.e. slow forcing frequencies) and moreover it is only valid for particles presenting some fluid slip at their surface. We present an alternative approach which obtains the fluid/particle force by enforcing the no-slip condition on the averaged fluid velocity at the particle domain. In doing so, particle/fluid momentum is exchanged instantaneously and inertia is taken into account. We are able to describe acoustic forces on colloidal particles, and grasp the effects of the finite size of the particle in the flow. Thermal fluctuations are also properly solved, as there is no extra dissipative channel associated to the particle friction. The code is written in CUDA and it is now running in local GPU's. Some information on the (wonderful) speed up of this architecture shall also be given. Possible generalizations and applications of the method shall be discussed.
F. Balboa and J. Bell and R. Delgado-Buscalioni and A. Donev and T. Fai and B. Griffit and C. S. Peskin. Staggered Schemes for Fluctuating Hydrodynamics, arXiv:1108.5188v1, (submitted, 2011)
F. Balboa and R. Delgado-Buscalioni, Particle Hydrodynamics using Hybrid Models: from Molecular to Colloidal Fluids, Particles 2011 (to appear)
F. Balboa, I. Pagonabarraga and R. Delgado-Buscalioni, Inertial coupling for point particle fluctuating hydrodynamics, (submitted, 2011).

DiagMC for the Anderson-Holstein model: Separation of timescales

Tuesday, 13th October 2011. 12:00-13:00

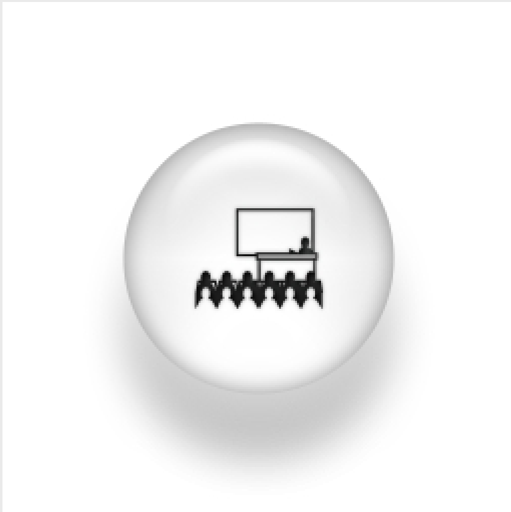


Klaus Ferdinand Albrecht
University of Freiburg
ABSTRACT:
Based on a recently developed diagrammatic real-time Monte-Carlo method [1], we access the nonequilibrium current of the spinless Anderson-Holstein model numerically

exact. For a certain parameter range, we found a separation of timescales for the current depending on its initial preparation.
[1] L. Muehlbacher and Eran Rabani, PRL 100, 176403 (2008).

Quantum transport of cold atoms

Wenesday, 5th October 2011. 12:00-13:00

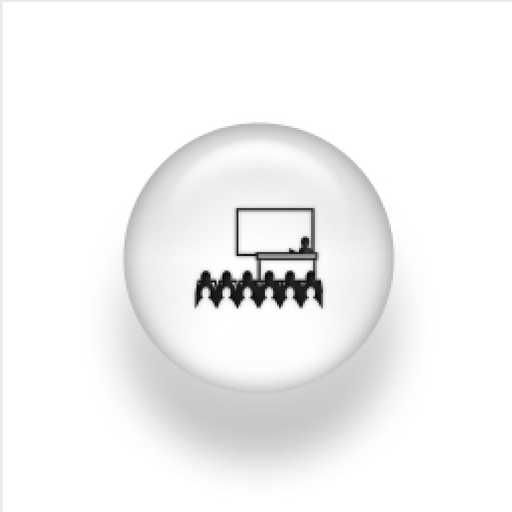


Fernando Sols
Universidad Complutense de Madrid
ABSTRACT:
Cold atom devices permit the exploration of novel forms of quantum transport that are difficult or impossible to realize in traditional electron transport setups. Under the action of an external driving, long-term coherent atom motion can be quite sensitive to the initial switching conditions even in the presence of interactions [1]. If the driving violates space- and time-inversion symmetry simultaneously, then coherent motion of a Bose-Einstein condensate in a given direction can be induced [2], as has been recently observed [3]. For weak driving, this coherent quantum ratchet stems from the interference between first- and second-order processes, as revealed by precise analytical work [4]. A different scenario is that of a leaking condensate passing through an interface which separates regions of subsonic and supersonic flow. On the supersonic (normal) side of the event horizon, we find the bosonic analog of Andreev reflection in superconductors [5]. On the other hand, the analog of Hawking radiation is emitted into the subsonic side, even at zero temperature. We study a double barrier structure which is predicted to emit resonant, highly non-thermal Hawking radiation [6].
[1] C. E. Creffield, F. Sols, Phys. Rev. Lett. 100, 250402 (2008); Phys. Rev. A 84, 023630 (2011).
[2] C. E. Creffield, F. Sols, Phys. Rev. Lett. 103, 200601 (2009).
[3] T. Salger, S. Kling, T. Hecking, C. Geckeler, L. Morales-Molina, M. Weitz, Science 326, 1241 (2009).

[4] M. Heimsoth, C. E. Creffield, F. Sols, Phys. Rev. A 82, 023607 (2010).
[5] I. Zapata, F. Sols, Phys. Rev. Lett. 102, 180405 (2009).
[6] I. Zapata, M. Albert, R. Parentani, F. Sols, New J. Phys. 13, 063048 (2011).

Collection and Concentration of Light by Touching Spheres: A Transformation Optics Approach

Wednesday, 8th June 2011. 12:00-13.00

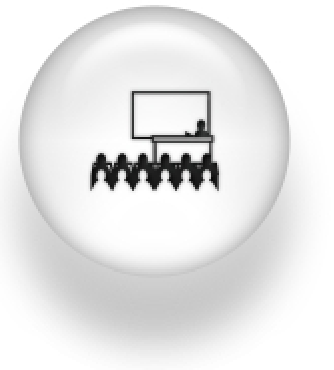


Prof. Antonio Fernández-Domínguez
Imperial College, London

ABSTRACT:
During the last decade, transformation optics has become the theoretical framework driving the development of metamaterial science. In this context, this elegant tool, which exploits the invariance of Maxwell's equations under coordinate transformations, provides the link between a desired electromagnetic effect and the material properties required for its occurrence. However, in the last year, several works have recovered the original purpose of this technique, first thought as a strategy to ease the solution of Maxwell's equations, by applying it to the study of the interaction of light with metal nanoparticles. In this talk, I will present a general three-dimensional transformation optics approach that yields analytical expressions for the relevant electromagnetic magnitudes in plasmonic phenomena at singular geometries. Specifically, I will focus on the study of the broadband response and superfocusing properties of touching metal nanospheres, and the prominent field enhancement that takes place at the point of contact between a spherical nanoparticle and a flat metal surface.

The Tau-3 lattice, graphene's big brother: transport and spectral properties

Tuesday, 31st May 2011. 12:00-13.00



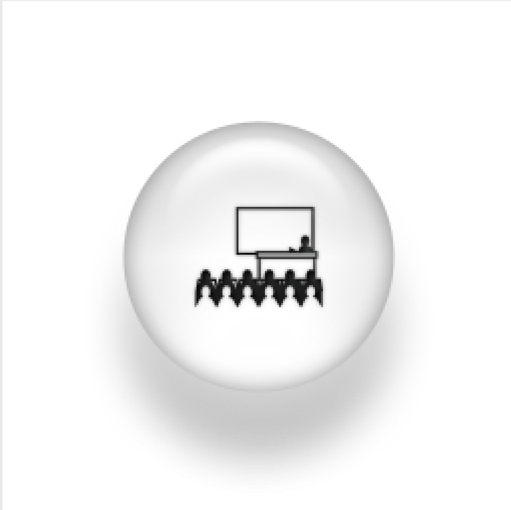
Prof. Daniel Urban
Freiburg University

ABSTRACT:
Albeit the Tau-3-lattice exhibits a reciprocal lattice similar to graphene with two inequivalent Dirac-points at six corners of the hexagonal first Brillouin zone, where relativistic electron-hole symmetric bands touch, Tau-3 differs and considerably generalizes graphene. Peculiarities of Tau-3 are the occurance of an additional dispersionless energy band at energy E = 0 and an enlarged pseudo-spin S = 1 instead of S = 1/2 as for graphene. This leads to an enhanced “super” Klein tunneling through rectangular electrostatic barriers, compared to the case of graphene. Moreover, at the particular energy of half the barrier height we find even complete transparency, T = 1, irrespective of barrier thickness and of incidence angle. We also investigate rectangular magnetic barriers and in this case identify regimes of zero barrier transparency, qualitatively similar to the case of graphene. Furthermore, we investigate the Tau-3 lattice (and other related 2-dimensional lattices) with respect to them becoming a topological insulator when spin/orbit interactions are present. Topological insulators are band insulators with large spin-orbit interactions that exhibit the quantum spin-Hall (QSH) effect. Physical phenomena driven by topological properties, have the appealing feature to be robust with respect to external perturbations. We investigate the transition between QSH and normal insulating phases under topological deformations of a two-dimensional lattice, namely transformations between the honeycomb and the Tau-3 lattice and propose a method for verifying our predictions with fermionic cold atoms in optical lattices.

Bercioux, Urban, Grabert, Häusler, Phys. Rev. A 80, 063603 (2009)
Bercioux, Goldman and Urban, Phys. Rev. A 83, 023609 (2011)
Goldman, Urban, Bercioux, arXiv:1101.4500 (PRA, in press)

2D nematics in a circular cavity

Wednesday, 25th May 2011. 12:00-13.00

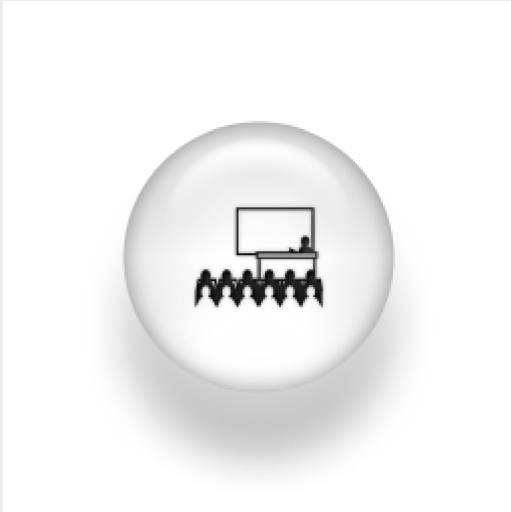


Prof. Enrique Velasco
Departamento de Física Teórica de la Materia Condensada, UAM

ABSTRACT:
In this informal seminar, we present our current work on confined two-dimensional nematics. A nematic is a fluid where particles are on average oriented along a particular direction, the director, which causes these material to be birefringent (hence their numerous applications) and to possess elasticity associated with director distortions. Even tiny bulk and surface external fields may have dramatic implications for the spatial dependence of the director. Frustration often occurs when the material is subject to competition due to conflicting fields, which generates defects in the samples. Here we discuss an interesting case where a 2D nematic is confined into a circular cavity; because of surface curvature, the inner surface creates a continuously varying favoured direction for the director near the surface which induces frustration in the whole sample. The material minimises the total free energy by creating defects which lower the total elastic distortion. A combination of Monte Carlo simulation, density-functional theory and experiments on vertically vibrated quasimonolayers of granular rods is used to unveil the apparently complex phase diagram. Preliminary results are presented as well as directions for future research.

Entanglement and Quantum Criticality

Wednesday, 18 May 2011, 12:00-13.00



Prof. Miguel Ibañez

Instituto Fisica Teorica UAM/CSIC

ABSTRACT:

After a brief introduction to the concept of quantum entanglement we will immediatly focus on some aspects of the role played by quantum information in the physics of many-body systems. We will expose the so called “area law”, which establishes an upper bound for the amount of entanglement in ground states of gapped Hamiltonians. Together with a 7-minute introduction to Conformal Field Theory we will then discuss the violation of the area law in one spatial dimension at criticality and the universal features exhibited by the ground state entanglement in this case [1]. Finally, a novel generalization of these results will be mentioned: the entanglement of critical excitations [2], a work which uncovers a further link between quantum information measures in 1d systems and the Conformal Field Theories describing their continuum limit.

[1] C. Holzhey, F. Larsen, L. Wilczek, Nucl. Phys. B 424, 443 (1994);

P. Calabrese, J. Cardy, J. Stat. Phys., 06 P06002 (2004).

[2] F. Alcaraz, M. Ibanez, G. Sierra, Phys. Rev. Lett., in press (2011).