SEMINARIO
Departamentos de Física Teórica I y II
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TITULO: Exploring synthetic quantum materials with ultracold fermions in a tunable-geometry optical lattice

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ABSTRACT

Ultracold atomic gases in optical lattices provide the opportunity of engineering synthetic quantum materials in a clean and highly controlled environment. On the one hand, these systems can be viewed as experimental quantum simulators for exploring challenging problems of condensed matter physics. On the other hand, they also allow for the realization of completely novel materials of interesting properties, without counterpart in solid-state systems.
In my talk, I will present recent experiments where an ultracold Fermi gas trapped in an optical lattice of tunable geometry is used to explore both aspects.
By loading non-interacting atoms into a honeycomb structure, we realize artificial graphene and observe the presence of two Dirac points in the band structure [1]. The flexibility of our experimental approach allows us to adjust the properties of these Dirac points at will, moving them inside the Brillouin zone and changing the effective mass of the associated Dirac fermions. Furthermore, we observe how the two Dirac points annihilate each other when coming too close together, a situation which is presently out of reach in solid-state samples.

Preparing instead a repulsively interacting gas of atoms in two different internal states, we implement the Fermi-Hubbard model and aim at simulating quantum magnetism in this system. In particular, we explore experimentally how certain crystal geometries favor the emergence of short-range magnetic order, and directly probe the nearest-neighbor spin correlations of the system [2]. In a dimerized lattice, the correlations manifest as an excess number of singlets as compared to triplets, whereas in an anisotropic simple cubic lattice we observe the appearance of antiferromagnetic correlations along one spatial axis.

[1] L. Tarruell, D. Greif, T. Uehlinger, G. Jotzu and T. Esslinger, “Creating, moving and merging Dirac points with a Fermi gas in a tunable honeycomb lattice”, Nature **483**, 302–305 (2012).
[2] D. Greif, T. Uehlinger, G. Jotzu, L. Tarruell and T. Esslinger, “Short-range quantum magnetism of ultracold fermions in an optical lattice”, Science **340**, 1307-1310 (2013).