Dirac cones, from graphene to cold atoms

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The so many fascinating properties of graphene are the subject of an intense research activity. There is also a growing interest for the study of "artificial graphenes", that is totally different and new systems which bear exciting similarities with graphene. The advantage of these structures is that they serve as new playgrounds for measuring and testing physical phenomena which may not be reachable in graphene, in particular the possibility of controlling the position of the pair of Dirac points existing in the electronic spectrum of graphene. In this talk, I will show how Dirac points can be manipulated, created or suppressed [1].

Recently, an experimental team in Zürich realized an ultracold gas of atoms moving in a potential landscape designed by laser fields [2]. Atoms now play the role of electrons and laser fields that of the crystalline lattice. This artificial graphene can be manipulated and deformed at will. Using this trick, the experimentalists managed to reach the required limit to observe the merging transition. By accelerating the atoms and measuring their evolution from low to high energy states, it is possible to follow the scenario of the merging transition. We have given a complete explanation of these experiments thanks to a model developed in our group [3]. We were able to compute the probability for an atom to get transferred from one band to the other as a function of the direction of acceleration. We have studied particularly the situation where atoms are accelerated along the axis of the two Dirac cones and experience two Landau-Zener transitions in a row. In this case, we expect the possibility of quantum interferences in momentum space leading to the yet to be observed Stückelberg oscillations [3].

Work done in collaboration with R. de Gail, P. Delplace, P. Dietl, J.N. Fuchs, M. Goerbig, L.K. Lim, F. Piéchon.

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[2] Creating, moving and merging Dirac points with a Fermi gas in a tunable honeycomb lattice, L. Tarruell, D. Greif, T. Uehlinger, G. Jotzu, T. Esslinger, Nature 483 (2012) 302

[3] Bloch-Zener oscillations across a merging transition of Dirac points, L.K. Lim J.-N. Fuchs, G. Montambaux, Phys. Rev. Lett. 108 (2012) 175303