MAR13-2012-020722

Abstract for an Invited Paper
for the MAR13 Meeting of
the American Physical Society

Tunable electron interactions and robust non-Abelian quantum Hall states in graphene and other Dirac materials[1]

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Discovery of the fractional quantum Hall effect inspired a concept of quasiparticles with non-Abelian exchange statistics. However, a major limitation for experimental studies of non-Abelian quasiparticles in traditional GaAs-based 2d systems is their lack of tunability: the effective electron interactions in such systems are fixed at values which make non-Abelian states either absent of very fragile. Therefore it is desirable to find alternative, tunable 2d systems that host robust non-Abelian quantum Hall states. In this talk, we will discuss the phase diagram of fractional quantum Hall states in recently discovered 2d Dirac materials (graphene, bilayer graphene, topological insulators). We will show that the effective interactions in these materials can be naturally tuned in a broad range, in contrast to GaAs. This tunability is achieved by external fields that control the mass gap of Dirac fermions. Alternatively, the effective interactions can be controlled by engineering the dielectric environment of the 2d Dirac electron gas. We will demonstrate that the tunability of interactions in Dirac materials allows one to stabilize non-Abelian states, as well as to drive phase transitions between various correlated phases (quantum Hall states, Fermi-liquid-like states, and states with broken translational symmetry) in a controlled manner. Connecting to experiments, we will argue that a very promising candidate material for tuning interactions and stabilizing non-Abelian states is bilayer graphene, where the gap can be naturally controlled by perpendicular electric field. Our study provides a realistic route towards engineering robust fractional and non-Abelian quantum Hall states in graphene and other Dirac materials.

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[2] Z. Papic, D. A. Abanin, Y. Barlas, R. N. Bhatt, Phys. Rev. B 84, 241306(R) (2011).
[3] D. Abanin, Z. Papic, Y. Barlas, R. N. Bhatt, New J. Phys. 14, 025009 (2012).

[1]This work was supported by DOE Grant DE-SC0002140Discovery of the fractional quantum Hall effect inspired a concept of quasiparticles with non-Abelian exchange statistics. However, a major limitation for experimental studies of non-Abelian quasiparticles