

The role of electron-electron interactions in graphene[†]

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About ten years ago, a new electronic material appeared – notable not only for its ease of preparation and theoretical simplicity, but also by its promise for future electronic devices. Single monatomic sheets of carbon, known as graphene, are described as weakly interacting massless Dirac fermions and in many ways, are a textbook system to test physical models. In this talk, I will begin by briefly reviewing the theory for graphene at the Dirac point where competing effects of disorder, electron-electron interactions, and quantum interference conspire together to give a surprisingly robust state whose properties can be described using a weakly-interacting semi-classical picture [1]. Motivated by some recent experiments in ultra-clean graphene, we use a combination of numerical and analytical techniques to address the role of electron-electron interactions at the Dirac point in the absence of disorder. By considering both the contact and long-range parts of the Coulomb interaction, we show that without strain, graphene remains metallic. But that a rather large – but experimentally realistic – uniform and isotropic strain provides a promising route to make graphene an antiferromagnetic Mott insulator [2]. Finally, we address the interaction enhancement of the Fermi velocity. Using quantum Monte-Carlo simulations with a long-range Coulomb tail, we identify two regimes: (i) a quantum critical point of the Gross-Neveu universality class, where the electrons form a strongly correlated Mott antiferromagnetic insulator, and (ii) a non-perturbative semi-metallic state characterized by a logarithmically diverging Fermi velocity. Most interestingly, we show that experimental graphene lies in the crossover between these two regimes, inheriting properties from both [3].

[1] S. Das Sarma, S. Adam, E. H. Hwang, and E. Rossi, “*Electronic transport in two dimensional graphene*”, *Rev. Mod. Phys.* **83**, 407 (2011).

[2] H. Tang, E. Laksono, J.N.B. Rodrigues, P. Sengupta, F.F. Assaad, and S. Adam, “*Interaction driven metal-insulator transition in strained graphene*”, *Phys. Rev. Lett.* **115**, 186602 (2015);

[3] H. Tang, J.N. Leaw, J.N.B. Rodrigues, P. Sengupta, F.F. Assaad, and S. Adam, “*The role of electron-electron interactions in graphene*”, *in preparation* (2016).

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