THREE SURPRISES IN GRAPHENE

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Graphene is a remarkable both for its unusual physical properties and for its elegant simplicity. Electrons in graphene are describable over a very wide range of energies by a twodimensional Dirac like model in which the honeycomb lattices sublattice degree of freedom acts like a pseudospin. I will review some of the most important low-energy electronic properties of graphene, including its frequency-independent universal conductivity, its remarkably large electrical conductivity, and the appearance of plasmaron features in its tunneling density-of-states emphasizing the important role of the sublattice psuedospin degree of freedom. I will also review three different unusual electronic states which may occur in graphene based two-dimensional electron systems, i) ferromagnets with an anomalous Hall effect and orbital magnetism but no spin-polarization, ii) excitonic superfluids and iii) states with momentum space condensate that support dissipationless currents. All three states have unusual broken symmetry and depend on many-body physics which flows from the interesting variety of band-structures that are achievable when two or more graphene layers are coupled by inter-layer tunneling or electron-electron interactions. Two-layer twodimensional Dirac systems which share most of the same properties also occur on the top and bottom surfaces of thin-film topological insulators. There is now (still controversial) experimental evidence for the first of the three surprising broken symmetry states, while the second and third stand as unconfirmed theoretical proposals. I will conclude my talk with a discussion of experiments which are key to progress in exploring this new many-body physics.