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Hydrodynamic transport, laminar flow, and the AdS/CFT viscosity bound in a graphene field effect transistor

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Graphene sheets encapsulated between crystals of boron nitride host a unique electron system that due to weak electron-phonon scattering allows micrometer-scale ballistic transport even at room temperature [1,2,3,4]. Above liquid nitrogen temperatures, these electron liquids are expected to display local equilibrium, enabled by strong electron-electron interactions [5]. Under these conditions, electrons in doped samples are expected to behave as a viscous liquid and may exhibit hydrodynamic phenomena akin to those observed in classical and quantum liquids. In this talk I will report on results of combined theoretical and experimental work [6,7] showing unambiguous evidence for this long-sought transport regime. In particular, I will discuss how high-quality graphene sheets in the Fermi liquid regime (k_B T ≪ E_F) exhibit an anomalous (negative) voltage drop near current injection points, which is attributed to the formation of whirlpools in the electron flow. Measurements of these quasi-local electrical signals enable to extract the value of the kinematic viscosity of the two-dimensional massless Dirac fermion liquid in graphene, which is found to be an order of magnitude larger than that of honey, in quantitative agreement with many-body theory [8]. Finally, I will discuss how our results near the charge neutrality point (k_B T≫ E_F) are compatible with the AdS/CFT viscosity bound [9,10].

Our work represents the first step towards the observation of nearly perfect fluidity and turbulence in solid-state devices.

Summary

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