Thermodynamic and transport properties of graphite at high magnetic field

Benoît Fauqué,[1,2] D. LeBoeuf,[3] C. W. Rischau,[2] G. Seyfarth,[3] S. Wiedmann,[4] and K. Behnia[2]

[1] *JEIP, USR 3573 CNRS, Collège de France, PSL Research University, 11, place Marcelin Berthelot, 75231 Paris Cedex 05, France.*

[2] *ESPCI ParisTech, PSL Research University; CNRS; Sorbonne Universités, UPMC Univ. Paris 6; LPEM, 10 rue Vauquelin, F-75231 Paris Cedex 5, France*

[3] *CNRS, Laboratoire National des Champs Magnètiques Intenses LNCMI, CNRS ,UGA, UPS, INSA, UPR 3228, F-38042 Grenoble Cedex 9, France*

[4] *High Field Magnet Laboratory (HFML-EMFL) and Institute for Molecules and Materials, Radboud University, Toernooiveld 7, 6525 ED Nijmegen, The Netherlands*

When a magnetic field confines the carriers of a Fermi sea to their lowest Landau level, electron-electron interactions are expected to play a significant role in determining the electronic ground state. Three decades ago it has been shown that graphite host a field-induced state driven by such interactions [1]. Here we will discuss our magneto-transport and ultra sound measurements at high magnetic field. Studying the magnetoresistance in graphite up to 80 T, we find that the magnetic field induces two successive phase transitions consisting of two distinct ordered states each restricted to a finite field window. In both states, an energy gap opens up in the out-of-plane conductivity and coexists with an unexpected in-plane metallicity for a fully gap bulk system. Such peculiar metallicity may arise as a consequence of edge-state transport expected to develop in the presence of a bulk [2]. The evolution of elastic constant anomalies with temperature and magnetic field across the first order state shows that it evolves in a sequence of 2nd order and first order thermodynamic phase transitions [3]. The complete phase diagram of graphite at high magnetic field is reported on Fig.1) and will be discuss in detail. If time allows I will also discuss the observation of magnetoconductance oscillations periodic in magnetic field with an amplitude of the order of $\frac{e^2}{h}$ in macroscopic samples of highly oriented pyrolytic graphite (HOPG) which can be explained by invoking moiré superlattices with a discrete distribution in periodicity [4].

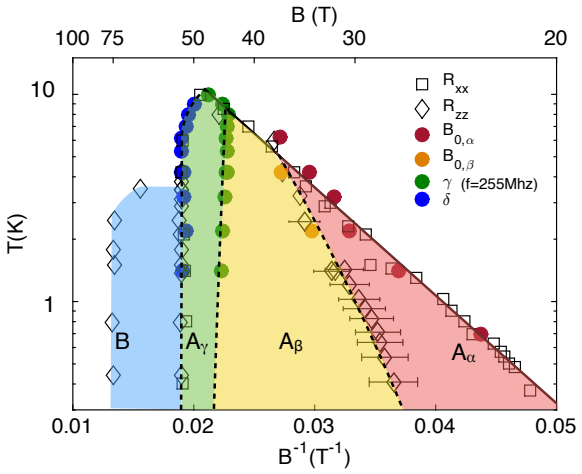

FIG. 1. *(B^{-1}, log(T)) phase diagram of graphite. Two main domes labeled dome A and dome B are found as a function of magnetic field. Dome A consists in a sequence of electronic phases labeled $A_{\alpha,\beta,\gamma,\delta}$ separated by thermodynamic phase transition lines labeled α,β,γ and δ, respectively. Ultrasound measurements (full circles) and transport measurements (R_{xx} and R_{zz} in black open squares and diamonds respectively). The black line associated with the α transition corresponds to the behavior expected from a BCS-like description of the DW transition. Dotted lines are guides to the eyes for the β, γ and δ-transition lines. Boundaries of dome B have been determined by R_{zz} [2]*

[1] S. Tanuma et al., in Physics in High Magnetic Fields, ed. S. Chikazumi and N. Miura (Springer, Berlin 1981)) [2] B.Fauqué et al., Phys. Rev. Lett., **110**, 266601 (2013) [3] D. Le Boeuf et al., Nat Com, **8**, 1337 (2017) [4] C. W. Rischau et al., Phys. Rev. B **95**, 085206 (2017)