Crossover between strongly coupled and weakly coupled exciton superfluids

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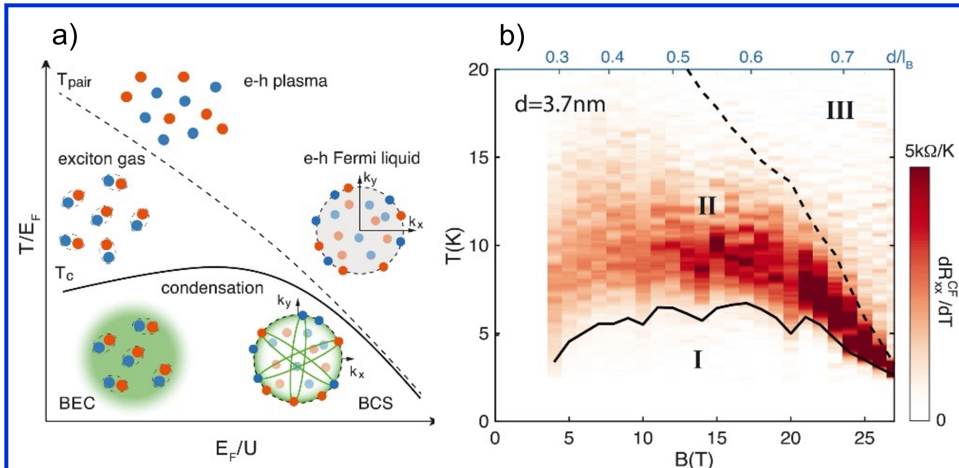
Funding Grants: Dean (DE-SC0019481; DMR-2011738), Kim (N00014-18-1-2877; W911NF-14-1-0247; ECS-00335765), Halperin (DMR-1231319), Hone (DMR-2011738), Taniguchi and Watanabe (PMJCR15F3), Liu (DE-SC0012260), G.S. Boebinger (NSF DMR-1644779)

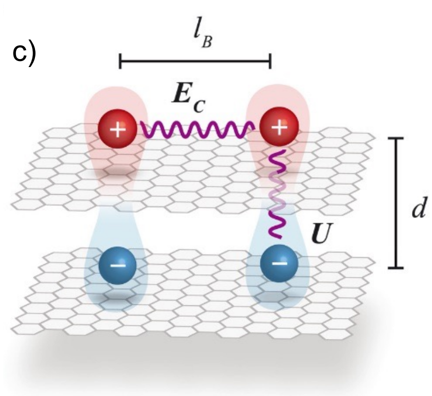
<u>Condensation of paired fermions into a quantum ground state represents one of the most spectacular many-body effects in strongly interacting systems</u>. Depending on the strength of the interactions, the paired fermions can be tightly bound – as in a Bose-Einstein Condensate (BEC) - or can be so large as to overlap with other pairs – as in Bardeen Cooper Schrieffer (BCS) pairing. *<u>Understanding that these two BEC and BCS pairing limits represent a continuum in a single phase diagram is one of the great theoretical achievements over the past century</u>*. Although well established in ultracold Fermi gas experiments, *<u>observation of BEC-BCS crossover in electronic systems has remained challenging owing to the limited ability to tune electron interactions in solid sate materials</u>*.

MagLab users studied graphene double layers separated by an atomically thin insulator. Under applied magnetic field, electrons and holes couple across the barrier to form bound magneto-excitons. *<u>Using temperature-dependent Coulomb drag and counterflow current measurements in bilayer graphene, researchers were able to continuously tune the magneto-exciton condensate through the entire phase diagram from strong to weak coupling</u>*. This tunability of fermion pairing in a solid-state device enables the investigating of fermion condensates of various pairing strengths and may lead to an improved understanding of the connection between the BEC-BCS crossover and unconventional superconductivity.



(a) Theoretical phase diagram for exciton condensates spanning strong to weak coupling regime. (b) Magneto-transport data verifying the expected boundaries of the phase diagram

c)



(c) Illustration of the quantum hall magneto-excitons in graphene double layers. Energy and length scales associated with exciton pairing in a graphene double-layer structure under a magnetic field can be widely tuned since the Interlayer Coulomb coupling U depends on the interlayer separation d, whereas intralayer Coulomb repulsion E_c is determined by the field dependent magnetic length l_B.

Facilities and instrumentation used: DC Magnet Facility, 31T resistive magnet

Citation: Liu, X.; Li, J.I.A.; Watanabe, K.; Taniguchi, T.; Hone, J.; Halperin, B.I.; Kim, P.; Dean, C.R., *Crossover between strongly coupled and weakly coupled exciton superfluids,* **Science**, **375** (6577), 205-209 (2022) doi.org/10.1126/science.abg1110