Spin and twist: theory of proximity exchange and spin-orbit coupling in graphene

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Graphene has weak spin-orbit coupling and no magnetic order. But when placed in contact to a strong spin-orbit coupling material, such as a TMDC, or a ferromagnet, such as $Cr_2Ge_2Te_6$, Dirac electrons acquire strong spin-orbit or exchange coupling, respectively. Such proximity effects render graphene suitable for spintronic applications that require spin manipulation [1]. In addition, graphene with strong proximity spin interactions can host novel topological states [2]. Fascinating new phenomena appear when bilayer graphene gets encapsulated by a TMDC from one side, and a ferromagnet from another. The resulting, so called ex-so-tic structure [3], offers spin swap functionality: switching spin-orbit and exchange coupling on demand by gate. In this talk I will review the recent developments in the proximity phenomena in graphene, and present some recent theoretical results on the control of the proximity spin-orbit and exchange coupling by twisting the van der Waals layers. I will show that the signature proximity spin-orbit coupling in graphene---valley Zeeman coupling---can be efficiently tuned by the twist angle [4], and that proximity exchange coupling can be switched by the twist angle, and even morph from ferromagnetic to antiferromagnetic [5]. Support from DFG SPP1244, SFB 1277, and EU GF is acknowledged.

References

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[2] P. Högl et al, Phys. Rev. Lett. 124, 136403 (2020)
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Figures

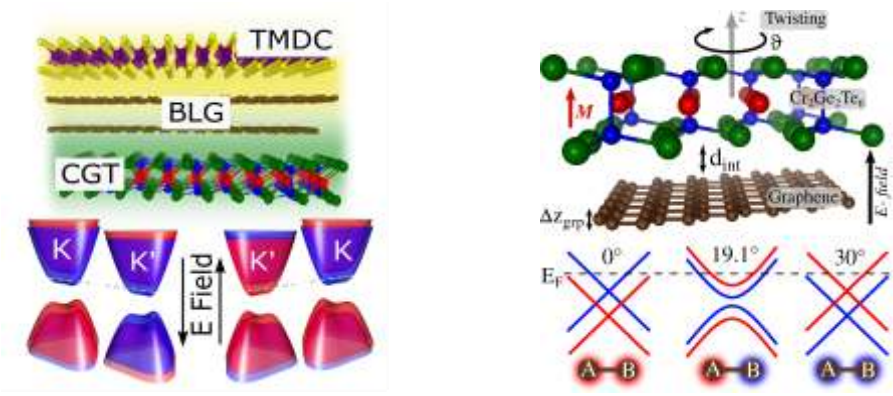

Figure 1: Left: Ex-so-tic heterostructure. Bilayer graphene (BLG) is encapsulated within a transition-metal dichalcogenide (TMDC) and ferromagnetic $Cr_2Ge_2Te_6$ (CGT). An electric field can swap, at a given chemical potential (dashed line) the exchange interaction (band structure on the left) and spin-orbit coupling (band structure on the right) [3]. Right: Depending on the twist angle between graphene and CGT, the Dirac electrons in graphene experience different exchange coupling. The coupling is opposite for 0 and 30 degrees, while at 19.1 degrees the coupling can be antiferromagnetic [5].