Superconductivity in graphene-based moiré systems

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Abstract

In the first part, we discuss band-widening and Fermi-velocity renormalization in twisted bilayer graphene due to Coulomb exchange interaction within an atomistic tight-binding model [1]. This renormalization leads to a down-shift of the magic angle θ_m by 0.1°. Our results may offer a microscopic explanation of the critical temperature T_c as function of the twist angle, see Figure. For larger twist angles θ>1.1°, T_c is dictated by the pairing instability which is obtained from the Bethe-Salpeter equation of the Cooper channel. For smaller twist angles θ<1.1°, T_c is limited by the superfluid density related to the critical line of the Berezinskii-Kosterlitz-Thouless phase transition.

In the second part, we investigate a related moiré system: sheared bilayer graphene [2]. Applying an electric field, a flat band emerges throughout the Brillouin zone at filling factor n=1 within a Hartree-Fock theory, displaying spin-valley locking. In the strong-coupling limit, exact diagonalization then yields a spin-valley density wave within the moiré unit cell and calculating the ground-state energy, we observe an odd-even effect as function of the number of induced holes. From this, we extract a (superconducting) gap of 12meV, leading to a critical temperature T_c≅150K.

References

[1] Miguel Sánchez Sánchez, José González, and Tobias Stauber, Phys. Rev. B **111**, 205133 (2025); arXiv:2508.12825

[2] José González, and Tobias Stauber, arXiv:2503.05624

Figure

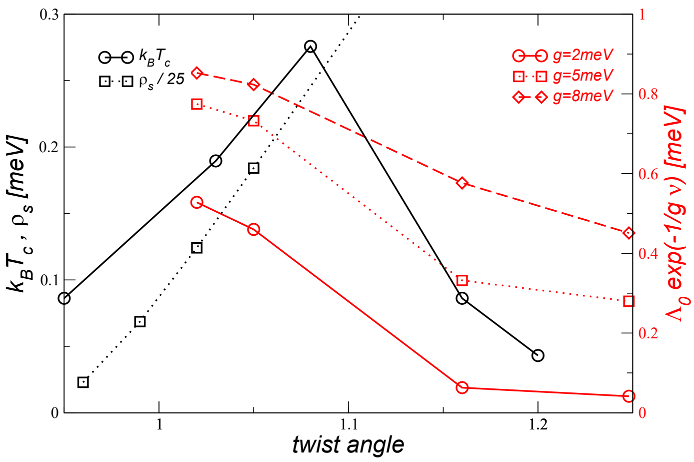

Figure 1: Comparison of the critical temperature k_BT_c taken from Y. Cao et al., Science **372**, 264 (2021) (black solid circles) and the superfluid stiffness ρ_s obtained from the Drude weight at optimal doping n=-2.4 using the Hartree-Fock renormalized bands (black dashed squares). Also shown is the critical temperature $k_BT_c=\Lambda_0\exp(-1/g\nu)$ coming from the Bethe-Salpeter equation with typical cut-off energy Λ_0=1meV, ν the renormalized density of states, and *g* the effective attractive interaction strength (*g*=2meV (red circle), *g*=5meV (red square), and *g*=8meV (red diamond)).