2D van der Waals Magnets: A Promising Platform for Strongly Correlated Phenomena

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Chromium trihalides are intriguing van der Waals materials known for their versatile magnetic properties, which hold promise for various spintronics applications. In recent years, extensive research has explored these magnetic insulators, both in bulk forms and atomically thin films. While much attention has been paid to investigating the magnetic behaviors of CrX_3 compounds and their layer-dependent properties, there has also been significant interest in integrating CrX_3 films into heterostructures with other two-dimensional (2D) materials, such as graphene. This integration aims to leverage the potential for proximitizing ferromagnetic exchange.

A noteworthy outcome of these studies has been the observation of significant charge transfer between graphene and CrX_3 reported by several research groups. This phenomenon is attributed to electrons occupying extremely narrow conduction bands within CrX_3. This observation paves the way for an intriguing avenue toward creating a 2D material that combines the highly mobile holes in graphene with the strongly correlated heavy electrons in CrX_3.

In our analysis, we focus on the properties of heavy electrons within such a system, specifically those belonging to the lowest spin-polarized conduction band of CrX_3, which is primarily governed by chromium d-orbitals. We develop an effective tight-binding model based on a minimal number of Cr orbitals, calibrated through comparison with density-functional theory calculations. Using this model, we investigate the charge transfer in a Graphene/CrI_3/Graphene heterostructure, estimating the Wigner parameter for the heavy electrons to be around r_s>20. This discovery suggests that Graphene-CrX_3 heterostructures offer a novel platform for exploring strong-correlated phenomena in spin-polarized 2D systems.