Design and realization of heavy-fermion quantum matter in van der Waals materials

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Van der Waals materials have allowed realizing a variety of emergent quantum states, including topological phases and unconventional superconductors. However, heavy-fermion correlated states, usually found in complex rare-earth compounds dominated by Kondo physics, have remained elusive in the two-dimensional world. The realization of heavy-fermion physics in two-dimensional materials would provide a whole new playground to explore exotic forms of quantum criticality, quantum magnetism, hidden order, and unconventional superconductivity. Here we show that van der Waals materials based on graphene and transition metal dichalcogenides allow realizing heavy-fermion states without rare-earth elements. First, we will theoretically show [1] how a heterostructure solely based on three layers of graphene allows realizing a tunable heavy-fermion state, whose full Doniach phase diagram can be explored by means of an interlayer bias. Second, we will show [2] the design and experimental realization of a heavy-fermion state in a 1H-TaS_2/1T-TaS_2 twisted dichalcogenide bilayer. Our results bring the physics of heavy-fermion rare-earth compounds to the two-dimensional world, opening a pathway towards designing and controlling a whole new family of correlated physics in moire van der Waals heterostructures.

[1] A. Ramires and **J. L. Lado**, *Phys. Rev. Lett. 127, 026401 (2021)*
[2] V. Vaňo, M. Amini, S. C. Ganguli, G. Chen, **J. L. Lado**, S. Kezilebieke, P. Liljeroth, *Nature 599, 582–586 (2021)*