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Gate-tunable Bose-Fermi mixture in a strongly correlated moiré bilayer electron system

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Abstract

Quantum gases consisting of species with distinct quantum statistics, such as Bose-Fermi mixtures, can behave in a fundamentally different way than their unmixed constituents. This makes them an essential platform for studying emergent quantum many-body phenomena such as mediated interactions and unconventional pairing. Here, we realize an equilibrium Bose-Fermi mixture in a bilayer electron system implemented in a WS2/WSe2 moiré heterobilayer with strong Coulomb coupling to a nearby moiré-free WSe2 monolayer. Absent the fermionic component, the underlying bosonic phase manifests as a dipolar excitonic insulator. By injecting excess charges into it, we show that the bosonic phase forms a stable mixture with added electrons but abruptly collapses upon hole doping. We develop a microscopic model to explain the unusual asymmetric stability with respect to electron and hole doping. By studying the Bose-Fermi mixture via monitoring excitonic resonances from both layers, we demonstrate gate-tunability over a wide range in the boson/fermion density phase space, in excellent agreement with theoretical calculations. Our results further the understanding of phases stabilized in moiré bilayer electron systems and demonstrate their potential for exploring the exotic properties of equilibrium Bose-Fermi mixtures.