Title: Unconventional superconductivity, topology and strong electronic correlations in two dimensional transition-metal dichalcogenide moiré bilayers

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Abstract:
Two dimensional (2D) moiré superlattices provide a highly controllable environment for exploring the intertwined effects of strong electronic correlations, nontrivial topology and unconventional superconductivity. Here we focus on the transition-metal dichlacogenide (TMD) bilayers which lead to a moiré pattern when two identical monolayers such as WSe_2 are stacked with a small twist angle or when different monolayers such as WS_2 and WSe_2 are combined even in the absence of twisting. The main aim of this study is to develop a unified theoretical understanding of unconventional superconducting state in TMD bilayers based on the effective low energy t−J and t−J−U models where the pairing mechanism originates from kinetic exchange in the moderately and strongly correlated regimes. In order to take into account the significant role of electron-electron interactions, we apply the Gutzwiller approximation method. Our analysis reveal several key features: (i) The emergence of topological superconductivity in twisted bilayer WSe_2 in the strongly correlated regime, revealing two topologically non-trivial superconducting domes characterized by mixed singlet (d+id)-wave and triplet (p−ip)-wave symmetry and a Mott insulating state at half-filling which is consistent with the early experimental report; (ii) In the moderately correlated regime and in the presence of intersite Coulomb repulsion term (V-term) we demonstrate that superconductivity emerges only within a narrow window of displacement field values, specifically when the Van Hove singularity aligns with half-filling, in qualitative agreement with the subsequent experimental data; (iii) We show that the negative U-Hubbard model, which results in conventional form of the paired state, does not fully resembles the experimental situation which additionally suggests that unconventional character of the paired state and significant role of electron correlations should be viewed as necessary ingredients of the theoretical description of superconductivity in WSe_2 homobilayer; (iv) Our numerical calculations show, that due to renormalization effects the considered pairing mechanism allows the superconductivity to persist even for relatively large values of V which are characteristic to WS_2/WSe_2 heterostructure, what emphasizes the potential of this system as another candidate for unconventional SC in the family of moiré flat band systems. Overall, this study establishes that the theoretical framework based on the t-J-U model provides a promising route towards unified description of SC in moiré TMD bilayers.