Twisted Kitaev bilayers

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The booming interest in quantum technologies and neuromorphic computing is driving the search of exotic phases of matter for futuristic applications. The recent discovery of van der Waals (VdW) materials (e.g., RuCl3, 1T-TaS2) that approximate the intriguing physics of quantum spin liquids [1] has attracted a large deal of interest. The quantum spin excitations (spinons) of such materials are predicted to behave as anyons [2] and intense research efforts have been put in proving their existence to harness their power for futuristic applications. Simultaneously, the capability of controlling the twist angle between stacked VdW materials and producing moiré superlattices (MSLs) has opened the possibility of engineering quantum phases with no counterpart in Nature [3]. Compared to conventional artificial systems, MSLs emerge at much smaller (nanometre) scales. Thus, emergent artificial phases can retain their quantum nature while being still relatively easy to be probed experimentally. Here we show that twisted bilayers of (Kitaev) quantum spin liquids, can exhibit unique phases as a function of the interlayer coupling [4]. By constructing a mean-field approximation in terms of solutions of commensurate bilayers, we show that the band structure of deconfined spinons is greatly modified and exhibits a hyper-magic manifold. A series of nearly perfectly flat bands appear at energies above the lowest gap, exhibiting a very large local (spinon) density of states that could potentially be probed in STM experiments. Intriguingly, flat-band eigenstates exhibit a localization akin to wavefunctions of Kagome lattices. These results prove that a wealth of novel phases of matter are hiding in twisted bilayers of the relatively less studied strongly-correlated VdW materials.

[1] A. Banerjee , J. Yan, J. Knolle, C. A. Bridges, M. B. Stone, M. D. Lumsden, D. G. Mandrus, D. A. Tennant, R. Moessner, and S. E. Nagler, Science 356, 1055 (2017).
[2] A. Kitaev, Annals of Physics 321, 2 (2006)
[3] Y. Cao et. al., Nature 556, 43 (2018); Y. Cao et. al., Nature 556, 80 (2018)
[4] S. Haskell and A. Principi, Phys. Rev. B 106, L161404 (2022)