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Non-Abelian anyons in the Kitaev spin liquid: stable realization and detectability via lattice defects

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Quantum spin liquids (QSLs) are exotic phases of matter characterized by strong entanglement and the absence of magnetic order even at zero temperature [1]. The spin-1/2 Kitaev model is a unique, exactly solvable example that hosts fractionalized excitations—Majorana fermions and Z_2 fluxes [2]. When time-reversal symmetry is broken, these excitations can give rise to non-Abelian Ising anyons, which are promising candidates for building blocks of topological quantum computation. However, stabilizing such anyons in this system remains challenging, as they are thermal excitations and do not appear in the ground state [2, 3]. Their detection is further complicated by the fact that, in QSLs, charge degrees of freedom are generally frozen, rendering conventional electric techniques—such as those used in fractional quantum Hall systems [4]—inapplicable.
This presentation theoretically investigates various lattice defects in the Kitaev spin liquid—such as higher-S (>1/2) magnetic impurities and spin vacancies—in connection with the stable realization and detection of Ising anyons. Our numerical and phenomenological studies show that spin-3/2 impurities can host stable anyon bound states in the ground state [5], similar to those found at spin vacancies [6]. Furthermore, we demonstrate that Ising anyons trapped at such lattice defects can be detected using local and nonlocal probes, including scanning tunneling microscopy [7] and NV center magnetometry [8], as spectroscopic techniques for observing the low-energy spectrum of fractionalized excitations.

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