Thermodynamic evidence for Majorana excitations in Kitaev spin liquid materials

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Kitaev spin liquids (KSLs) are an exotic quantum state of matter that could host elusive Majorana fermions [1]. However, detecting these spin liquids is challenging. Unlike conventional magnets, they lack magnetic order, making them invisible to standard scattering techniques. Additionally, Majorana fermions are electrically neutral, complicating electrical measurements. In our research, we took an alternative approach: leveraging the fact that Majorana fermions contribute to entropy and that their excitation spectra vary with the direction of an applied magnetic field. By measuring how heat capacity changes with the magnetic field angle, we sought to identify KSL behavior. In the prime candidate material α-$RuCl_3$, we find a distinct closure of the low-energy bulk gap is observed for the fields in the Ru-Ru bond direction, and the gap opens rapidly when the field is tilted. This is the hallmark of an angle rotation–induced topological transition of fermions, providing conclusive evidence for the KSL with Majorana quasiparticles [2,3]. In contrast, in $Na_2Co_2TeO_6$, which was considered a promising 3*d* KSL candidate due to potentially stronger Kitaev interactions than the 4*d* electron systems, the behavior was markedly different; the field-angular dependence of specific heat shows opposite behavior to the expectation in the KSL [4]. This finding suggests that $Na_2Co_2TeO_6$ is not a KSL, but exhibits topological magnon excitations. Our study demonstrates that angular-dependent heat capacity measurements provide a powerful tool for distinguishing true Kitaev spin liquids.

References:

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