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Prodding the quantum spin liquid

The hunt for a quantum spin liquid continues with new materials and more refined methods leading the way.

A system of spins that are highly entangled but do not order magnetically down to the lowest temperatures may be considered a quantum spin liquid (QSL). While it is generally the case that scientists rarely measure the physical observable they are trying to probe, this line of reasoning is even more pronounced for the case of a QSL, which harbours a rather featureless ground state. Condensed-matter physicists have been searching for signatures of a QSL for decades on magnetically frustrated lattices such as the triangular lattice in organic salts and the kagome lattice in herbertsmithite[1]. Much attention has turned to honeycomb lattice materials since the discovery of the exactly solvable spin-1/2 Kitaev model with bond-dependent exchange interactions[2] (Fig. 1), whose elementary excitations include Majorana fermions — widely touted for their potential in quantum computation. In this issue of *Nature Materials*, we present three original research articles and two News & Views articles focused on candidate Kitaev materials.

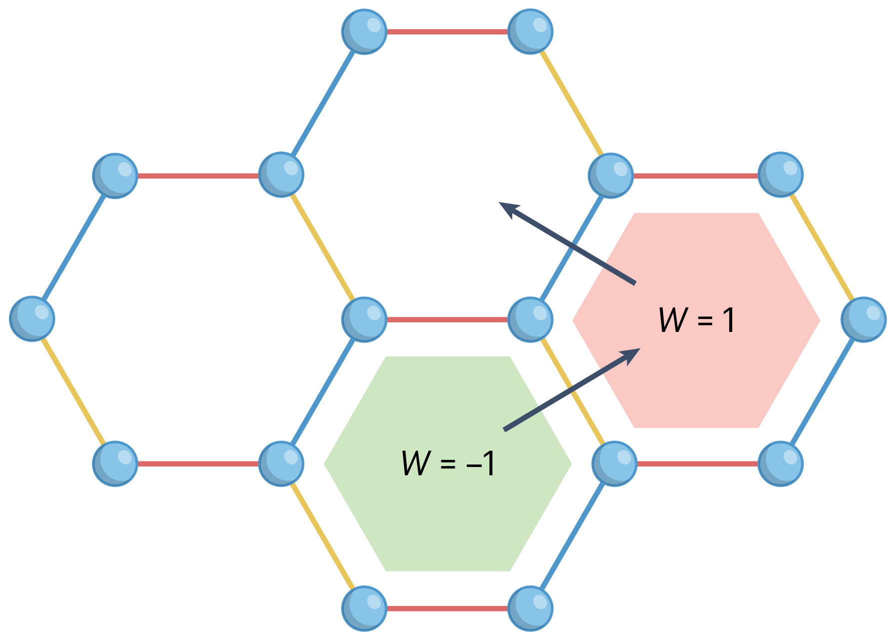

Fig. 1 | Bond-dependent exchange interactions (coloured lines) between spins (present on the blue atomic sites) on a honeycomb lattice. In the Kitaev model, the spins fractionalize into Majorana fermions (arrows) and local gauge fluxes with two possible states $W = \pm 1$. Figure reproduced with permission from the News & Views article by Miao and Halász.

The 4*d* transition metal compound $RuCl_3$ in a magnetic field is considered a prime candidate for realization of the Kitaev model. For example, much excitement was recently elicited by the report of a half-quantized thermal Hall conductance in $RuCl_3$ consistent with the presence of Majorana fermions[3], but these measurements have proven difficult to reproduce. In a Letter in this issue, Phuan Ong and collaborators report thermal Hall conductance measurements over a broad range of temperature and magnetic field that are non-quantized and can be accounted for by topological bosonic modes in a Chern insulator-like model. In the corresponding News & Views article, Hae-Young Kee points out the experimental difficulties in reconciling thermal measurements of $RuCl_3$ due to the different stacking arrangements possible in this van der Waals material.

Such weak interlayer bonding is taken advantage of by Adam Tsen and collaborators to exfoliate few-layer $RuCl_3$ and probe its properties by a broad range of techniques, as they report in an Article in this issue. Intriguingly, they find that tiny lattice distortions switch the magnetic anisotropy from easy-plane to easy-axis, pushing this monolayer material into a region of the phase diagram where a QSL may be more forthcoming. As pointed out in the corresponding News & Views article from Hu Miao and Gábor Halász, we can anticipate thermal Hall measurements on such few-layer samples in the coming years.

Peter Armitage and collaborators report in an Article their time-domain terahertz spectroscopy measurements on a different effective spin-1/2 compound with 3*d* transition metal atoms on a honeycomb lattice, $BaCo_2(AsO_4)_2$. They report a broad magnetic continuum consistent with fractionalized particles, as well as the suppression of long-range magnetic order by rather small magnetic fields. They hope that these promising results will push the community to further probe this QSL candidate.

An outstanding issue in the quest for a QSL is providing definitive signatures of its existence. Recent work featuring cold atoms on a kagome lattice probed the QSL by topological string operators[4]. Thermal measurements on more ideal materials might provide the answer, or advanced spectroscopic tools sensitive to the entanglement in condensed matter. It is clear that the collective effort of a broad range of materials scientists with expertise in various materials and methods will be required to address this open problem.

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