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Thermal-transport Studies of Quantum Spin Liquids

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Quantum spins, coupling antiferromagnetically on a 2D triangular lattice, cannot simultaneously satisfy all interactions. This frustrated situation is expected to give rise to mysterious fluid-like states of spins without long- range order, so called quantum spin liquid (QSL). The ground state of QSL and its exotic phenomena, such as fractionalized excitation with an artificial gauge field, have been extensively discussed for decades, yet to be identified by lack of any real materials. This is why the recent discoveries of materials possessing an ideal 2D triangular lattice have spurred a great deal of interest. To understand the nature of QSL, knowledge of the low-lying excitation, particularly the presence/absence of an excitation gap, is of primary importance. We employ thermal transport measurements on newly discovered QSL candidates, κ-(BEDT-TTF)$_2$Cu$_2$(CN)$_3$ and EtMe$_3$Sb[Pd(dmit)$_2$]$_2$, and report that the two organic insulators possess different QSLs characterized by different elementary excitations. In κ-(BEDT-TTF)$_2$Cu$_2$(CN)$_3$ [1], heat transport is thermally activated in low temperatures, suggesting presence of a spin gap in this QSL. In stark contrast, in EtMe$_3$Sb[Pd(dmit)$_2$]$_2$ [2], a sizable temperature-linear term of thermal conductivity is clearly resolved in the zero-temperature limit, showing gapless excitation with long mean free path ($\sim$1,000 lattice distances), analogous to excitations near the Fermi surface in normal metals. These results are consistent with theoretical suggestions including 2D gapless spinons with a Fermi surface. This work was done in collaboration with N. Nakata, Y. Senshu, M. Nagata, Y. Kasahara, S. Fujimoto, T. Shibauchi, Y. Matsuda, T. Sasaki, N. Yoneyama, N. Kobayashi, H. M. Yamamoto and R. Kato.

[1] M. Yamashita *et al.*, Nature Physics **5**, 44- 47 (2009).
[2] M. Yamashita *et al.*, Science **328**, 1246 (2010).