What is the heat carrier of planar thermal Hall conductivity in the Kitaev quantum spin liquid candidate $RuCl_3$? +

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The planar thermal Hall effect in the magnetic field-induced quantum spin liquid state of $RuCl_3$ has been a subject of debates. Experimental results reported so far have not converged, which led to quite different proposals for the microscopic mechanism behind the observed thermal Hall signal, including Majorana edge state [1], topological magnons [2] and phonons [3]. We measured the thermal conductivity κ_{xx} and the thermal Hall conductivity κ_{xy} on two single crystals grown by different methods, Bridgman and CVT. While the Bridgman crystal showed κ_{xy} close to the half-quantized value κ_{HQ} at low temperatures below ~6K and high fields above ~11T [4], the CVT crystal showed much reduced κ_{xy}, a factor of 5 smaller than those of Bridgman crystal and hence κ_{HQ} in the corresponding field and temperature range. Despite the much reduced κ_{xy} in the CVT crystal, the thermal Hall angle κ_{xy} / κ_{xx} was found to be not so different between the two crystals over a wide field and temperature range, suggesting a scaling of κ_{xy} with κ_{xx}. The scaling poses certain constraints on the Majorana edge and topological Hall scenarios and suggests that the substantial part of the Hall heat current may be carried by phonons dominating κ_{xx}. As a reference, we show that phonons contribute significantly to the thermal Hall current in the 2D Dirac system $EuMnBi_2$ through a phonon drag.

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