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Absence of magnetic thermal conductivity in the quantum spin liquid candidate $YbMgGaO_4$

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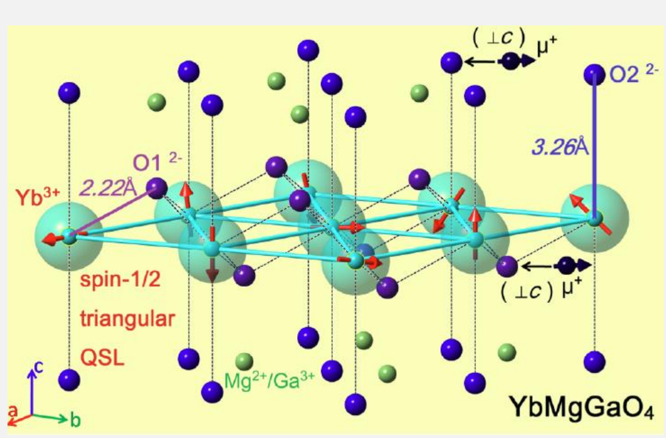
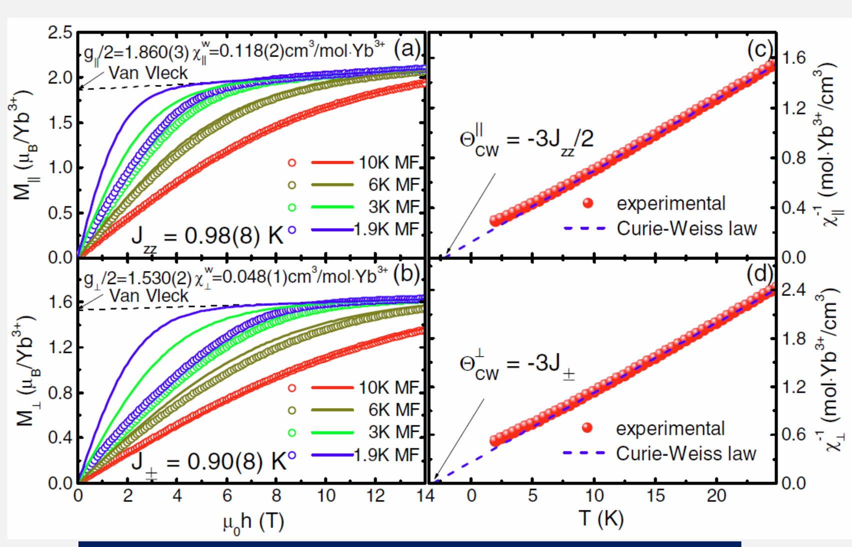
We present the ultralow-temperature specific heat and thermal conductivity measurements on single crystals of $YbMgGaO_4$, which was recently argued to be a promising candidate for a quantum spin liquid (QSL). In a zero magnetic field, a large magnetic contribution of specific heat is observed, and exhibits a power law temperature dependence ($C_m \sim T^{0.74}$). On the contrary, we do not observe any significant contribution of thermal conductivity from magnetic excitations. In magnetic fields $H \geq 6$ T, the exponential T dependence of C_m and the enhanced thermal conductivity indicate a magnon gap of the fully polarized state. The absence of magnetic thermal conductivity at the zero field in this QSL candidate puts a strong constraint on the theories of its ground state.

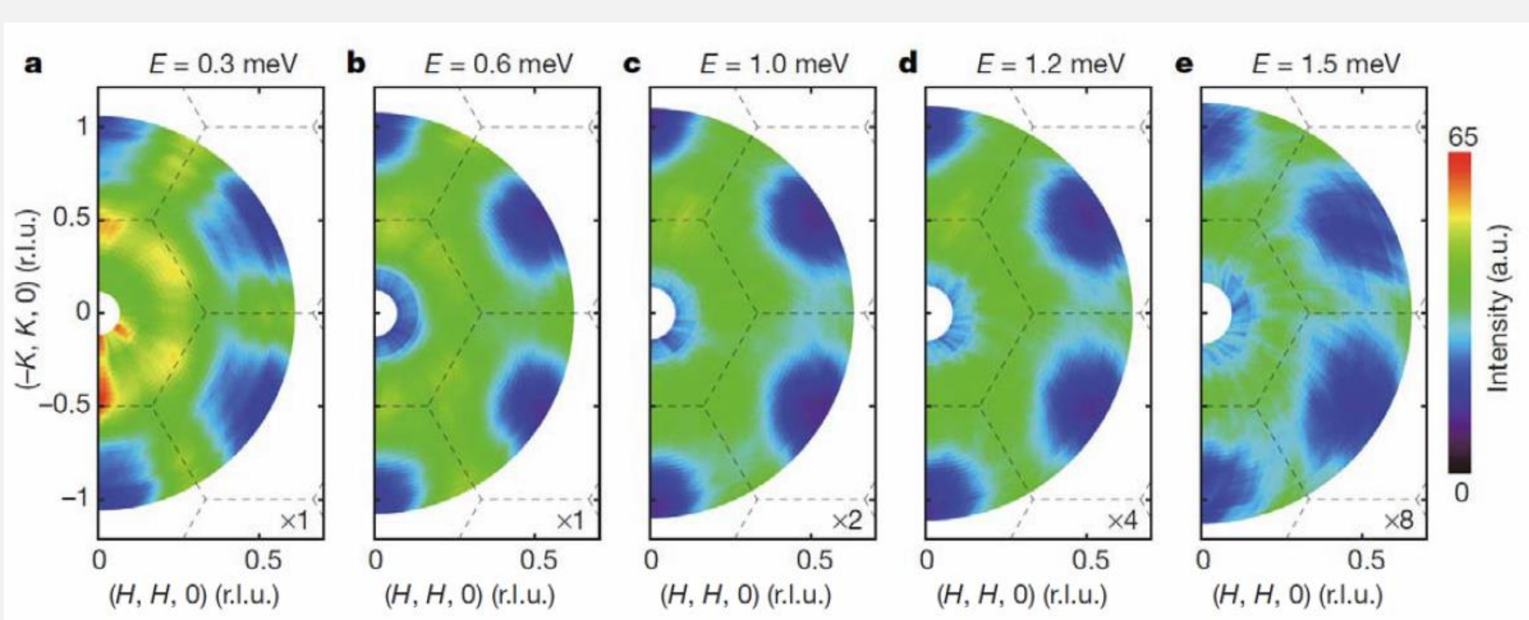
$YbMgGaO_4$: a QSL candidate

2D triangular lattice of spin-1/2 Yb^{3+}



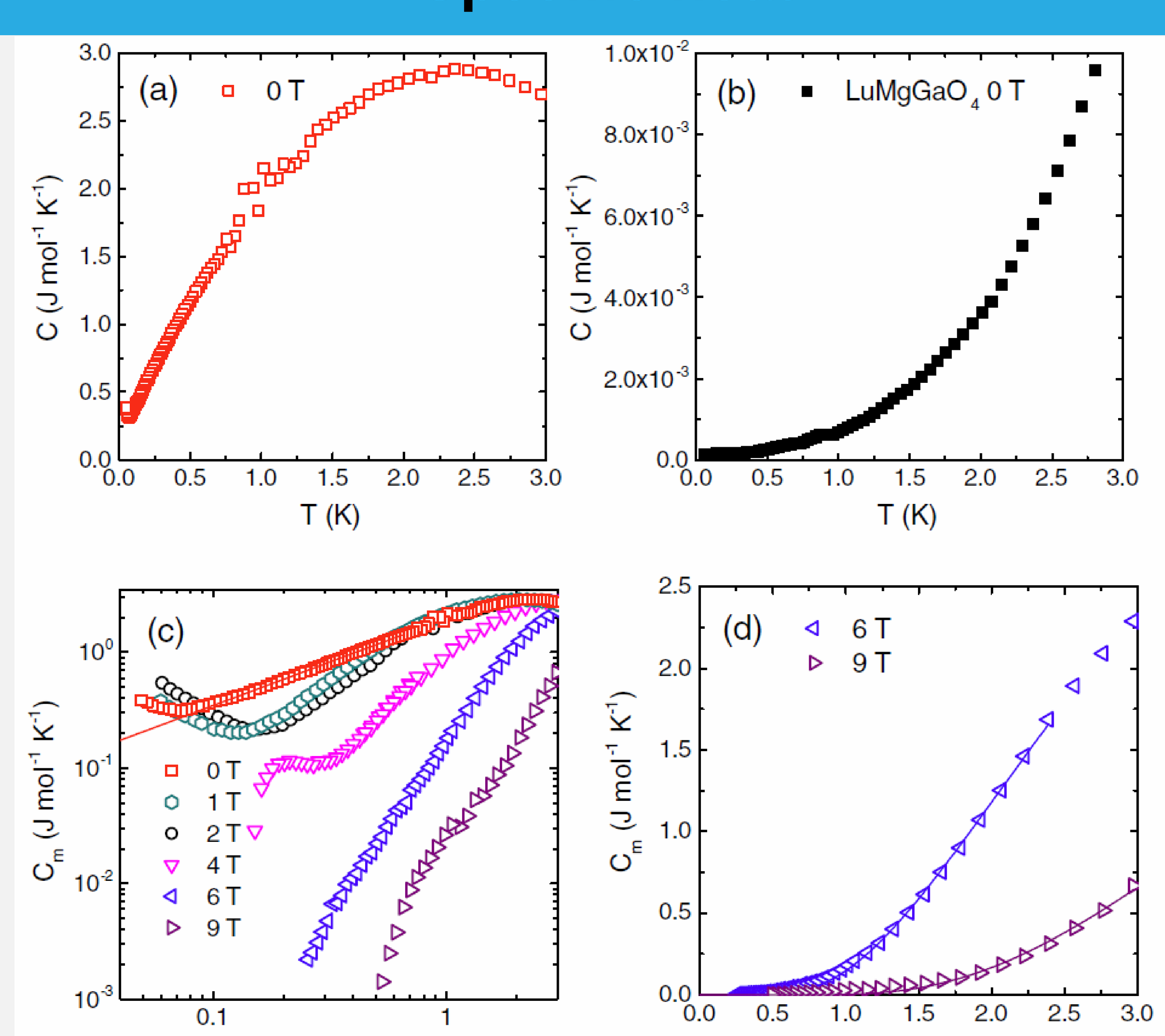


Magnetization and magnetic susceptibility



A broad continuum of spin excitations, which is a hallmark of the QSL state, was observed in neutron scattering measurements

Specific heat



Zero-field specific heat: well fitted by $C_m = cT^{\beta}$ with β = 0.74, close to 2/3.

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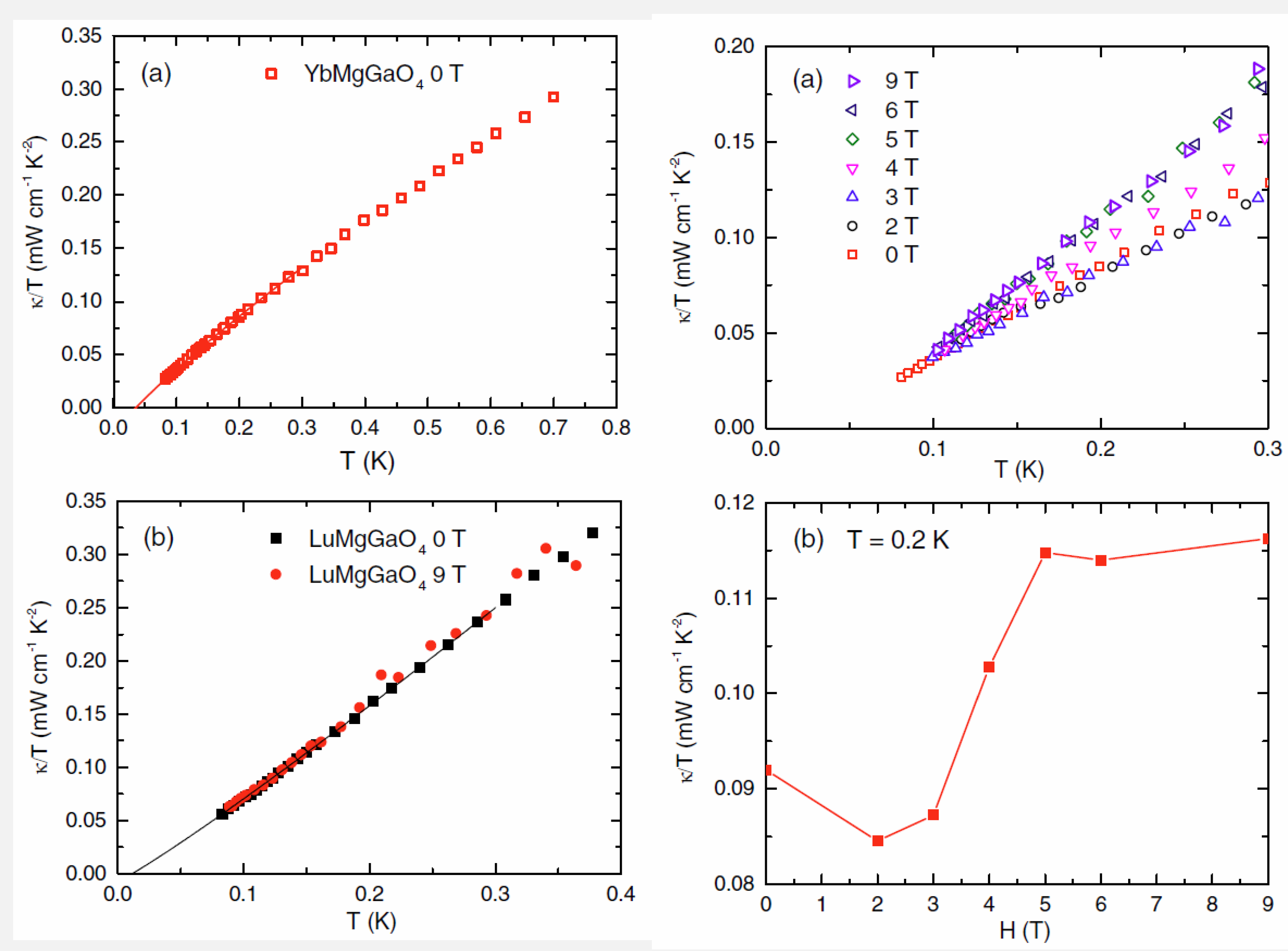
A gapless U(1) QSL with a spinon Fermi surface according to Ref. [5]

Magnetic field rapidly suppresses the C_m. The temperature dependence of the C_m gradually turns into an exponential one, which is attributed to the magnons with a gap in a fully polarized state.

Thermal transport properties



At zero field, κ_0/T is negative, and the power of the temperature dependence is abnormally lower than 2. The κ/T first decreases slightly for $H < 2$ T, then there is a sharp increase between 2 and 5 T, and it finally saturates for $H > 5$ T. While the magnetic state of $YbMgGaO_4$ in the intermediate fields ($0 < H < 5$ T) is rather complex, it simply tends to become a fully polarized state for $H > 5$ T at such low temperatures. In the fully-polarized state with a magnon gap of several Kelvins, there are almost no magnetic excitations to scatter phonons below 0.3 K; therefore, the κ of $YbMgGaO_4$ at $H > 5$ T is purely contributed by phonons. At lower fields, it is the additional scattering of phonons by magnetic excitations that suppresses the κ and gives the abnormal temperature dependence of κ and the unphysical negative κ_0/T for $YbMgGaO_4$.

Discussions

- **The absence of magnetic thermal conductivity at zero field means that either (a) the presumed gapless spinons do not exist in $YbMgGaO_4$ and the large C_m has some other magnetic origin; or (b) the gapless spinons do exist but for some reason they do not conduct heat significantly in $YbMgGaO_4$. One possible mechanism of the spinon localization may be the disorder of Mg^{2+}-Ga^{3+} sites (random occupation) in the double layers of Mg/GaO_5 triangular bipyramids.**
- **Recently, we've measured the ultra-low temperature a.c. susceptibility of $YgMgGaO_4$, which exhibits a spin-glass transition at ~0.1K, indicating that the ground state of $YgMgGaO_4$ is a spin glass.**

References

(Only major ones listed):

[1] M. Yamashita *et al.*, Nat. Phys. **5**, 44 (2009).

[2] M. Yamashita *et al.*, Science **328**, 1246 (2010).

[3] Y. S. Li *et al.*, Sci. Rep. **5**, 16419 (2015).

[4] Y. S. Li *et al.*, Phys. Rev. Lett. **115**, 167203 (2015).

[5] Y. Shen *et al.*, Nature **540**, 559 (2016).

[6] J. A. M. Paddison *et al.*, Nat. Phys. **13**, 117 (2017).

Y. Xu *et al.*, Physical Review Letters 117, 267202 (2016).