Ballistic magnon heat transport in the quasi-one-dimensional $S = 1/2$ antiferromagnet Sr_2CuO_3

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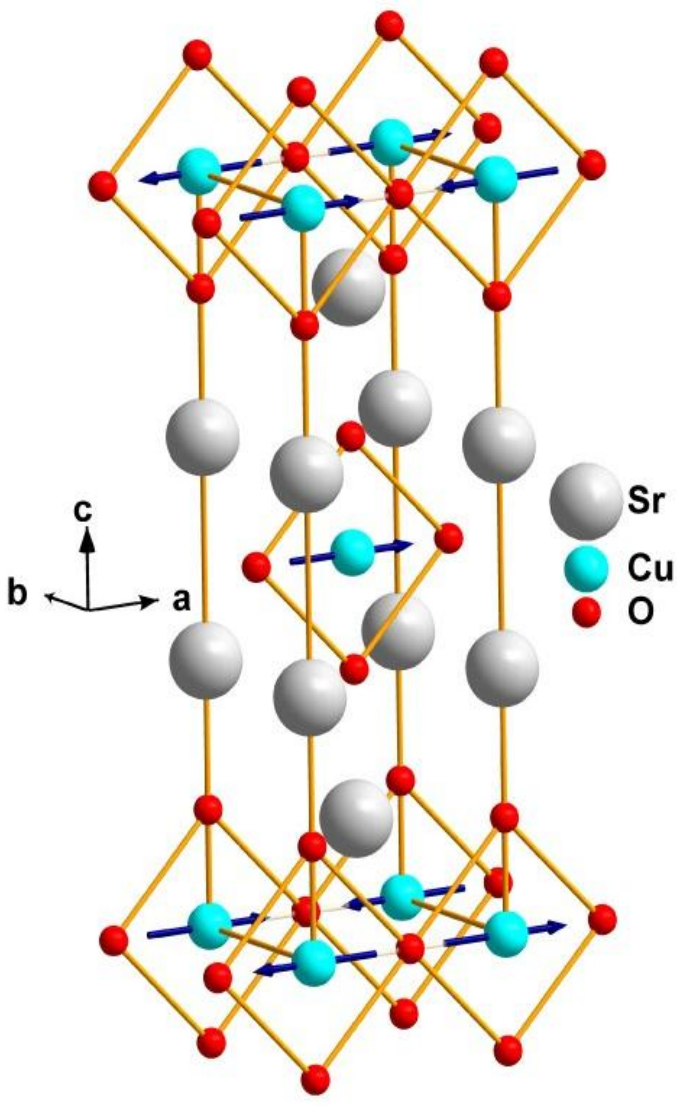
We report the heat transport study of the quasi-one-dimensional (1D) antiferromagnet (AF) Sr_2CuO_3 down to 50 mK, with the heat current along the directions parallel $\kappa_{//}$ and perpendicular $\kappa_{\perp}$ to the spin chains. From 50 mK to 0.5 K, well below $T_N = 5.41$ K, both the thermal conductivity $\kappa_{//}$ and $\kappa_{\perp}$ show T^3 dependence, suggesting ballistic boson heat transport limited by boundary scattering. Moreover, $\kappa_{//}$ is about 40% higher than $\kappa_{\perp}$. For two samples with comparable crosssection area, this extra heat conduction along spin chains is attributed to the three-dimensional (3D) antiferromagnetic magnons, which have a few orders higher velocity along chain than perpendicular to the chain. The magnetic field shows no effect on the thermal conductivity up to 14.5 T. Our results help to understand the strongly anisotropic heat transport in spin-chain compounds at temperature above 1 K.

1D AF Heisenberg spin-1/2 cuprate

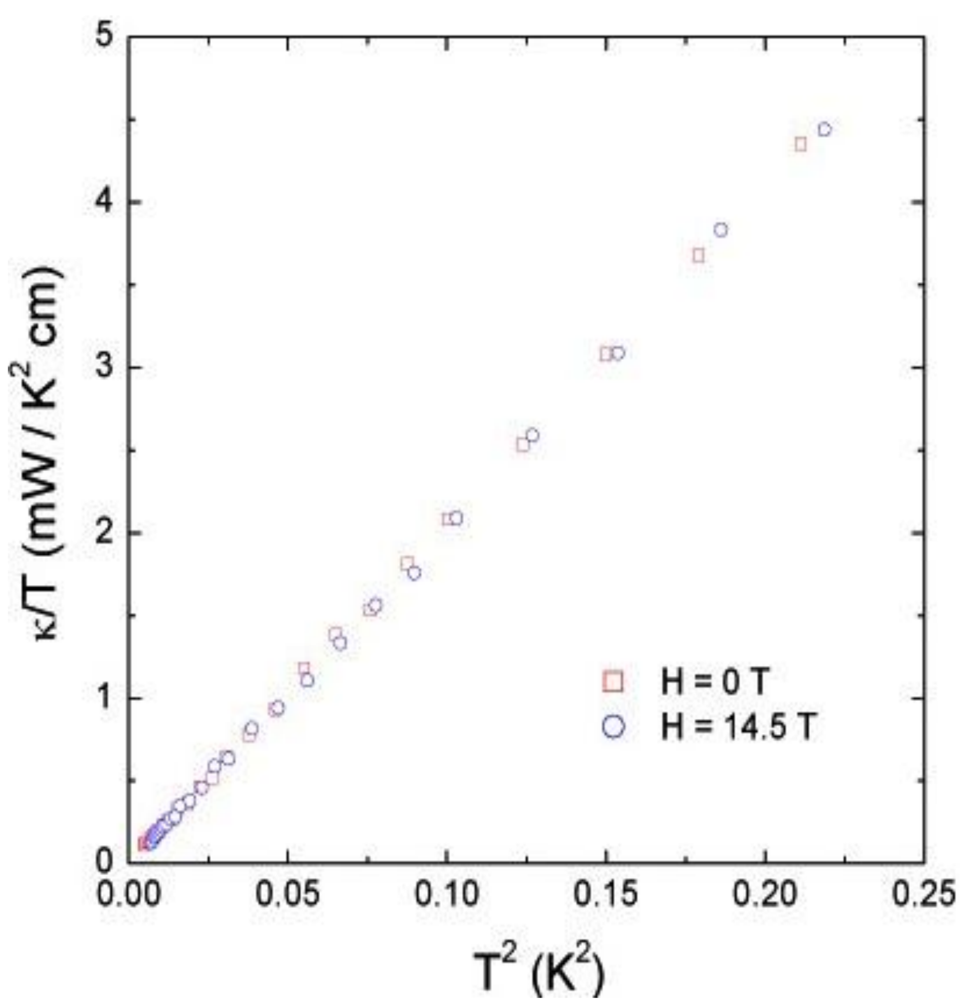
- Fractionalize electrons: spin-charge separation[1]
- Extract spinon thermal conductivity[2]
- Benefit to understand the mechanism underlying the high-temperature superconductivity

Crystal structure of Sr_2CuO_3



- Orthorhombic Immm space group[3]
- a-axis:
  - parallel to the spin chains;
  - CuO_4 tetragons sharing O corners;
  - strong AF intrachain coupling J/k_B between 2150 K and 3000 K.
- b- and c-axes:
  - perpendicular to the spin chains;
  - the nerghboring Cu^{2+} ions do not share oxygen ions;
  - weak interchain coupling $J' = k_B T_N$;
  - N éel Temperature $T_N = 5.41$ K.[4]
- smallest coupling ratio J'/J
- isotropic phonon transport

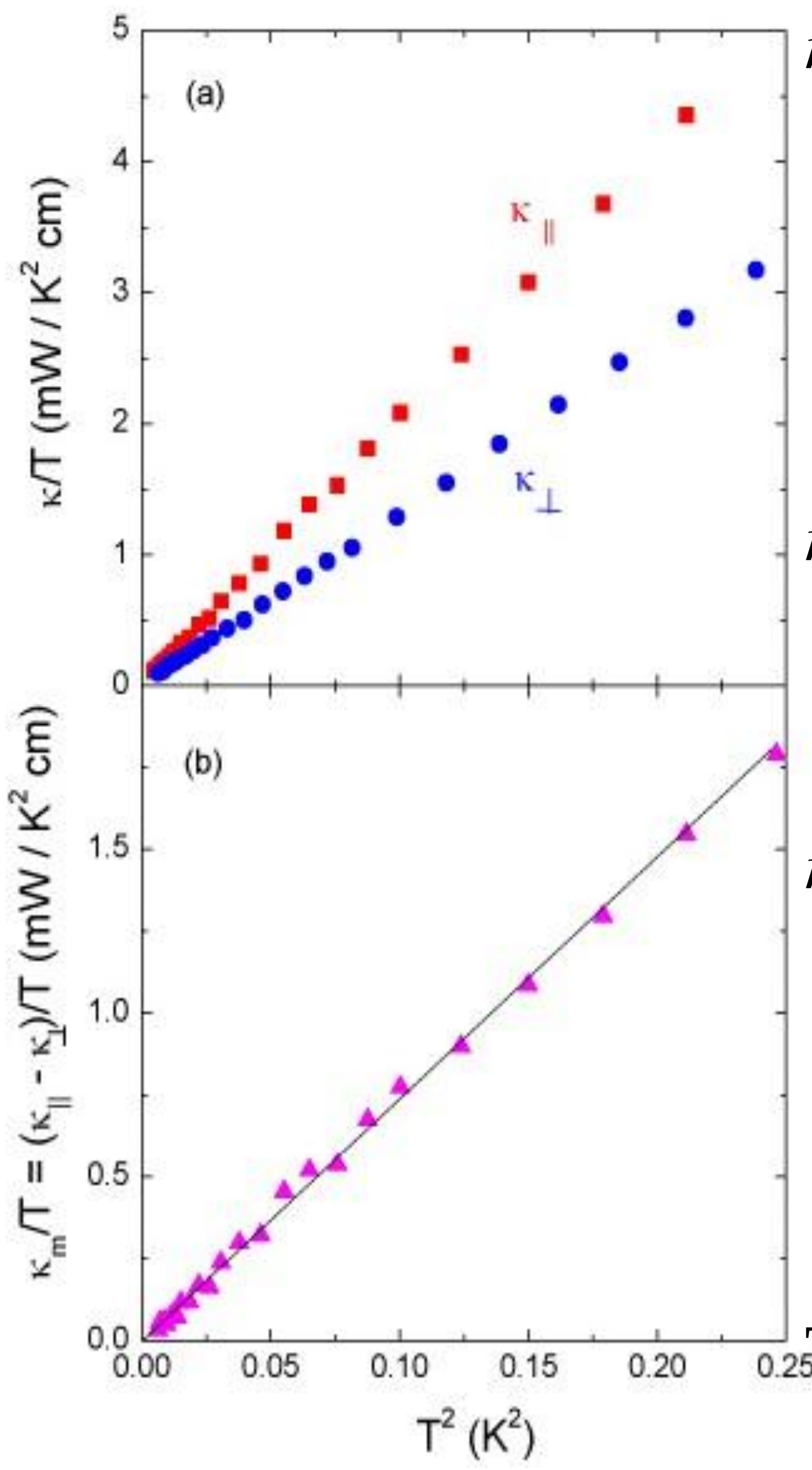
Field dependence of the thermal conductivity



The thermal conductivity κ of Sr_2CuO_3 single crystal under magnetic fields $H = 0$ T and 14.5 T, at the temperature from 50 mK to 0.5 K, with the heat current and magnetic field along the chains, no differences.

The saturation field $B_c = 2J/g\mu_B$ ~3000 T is too high for laboraries.

Thermal conductivity along the a- and c-axes and magnon thermal conductivity



$\kappa_{//}$: thermal conductivity along the spin chains, at the temperature from 50 mK to 0.5 K, T^3 dependence, no residual linear term κ_0/T, the sum of phonon and magnon thermal conductivities.

$\kappa_{\perp}$: thermal conductivity perpendicular to the spin chains, T^3 dependence, $\kappa_0/T \approx 0$, only phonon conductivity.

$\kappa_m = \kappa_{//} - \kappa_{\perp}$: the 3D AF magnon thermal conductivity, limited by boundary scattering, the velocity of magnon along the chains $v_{m//} \sim J$ is a few orders higher than $v_{m\perp} \sim J'$,so only $v_{m//}$ is counted.

The solid line represents a fit of the data to $\kappa/T = a + bT^{\alpha-1}$, giving $\alpha = 3$, no residual linear term κ_0/T.

Conclusions

We have detected the magnetic excitation in the AF long range order state of the quasi-1D Heisenberg spin-1/2 chain cuprate Sr_2CuO_3, using ultra-low-temperature thermal conductivity measurements. The ballistic magnon thermal conductivity limited by boundary scattering is obtained. Our work has reveal the magnetic excitation at the temperature far below the N éel temperature, which has not been done before.

References

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