Giant isotropic magneto-thermal conductivity of metallic spin liquid candidate $Pr_2Ir_2O_7$ with quantum criticality

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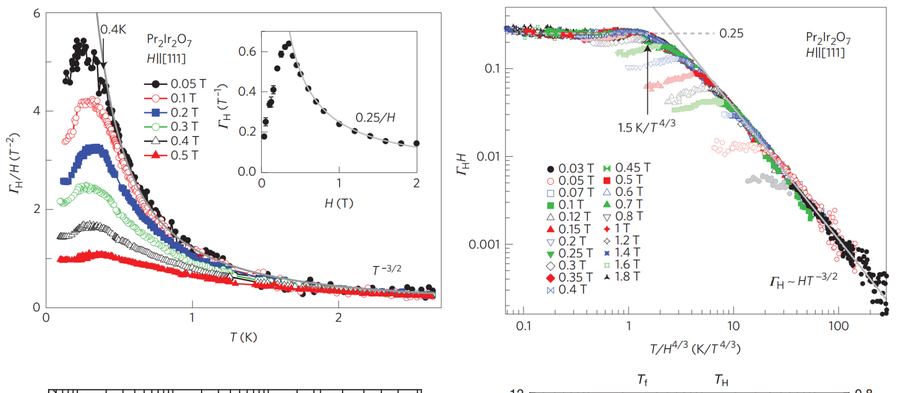
Introduction

Quantum critical point

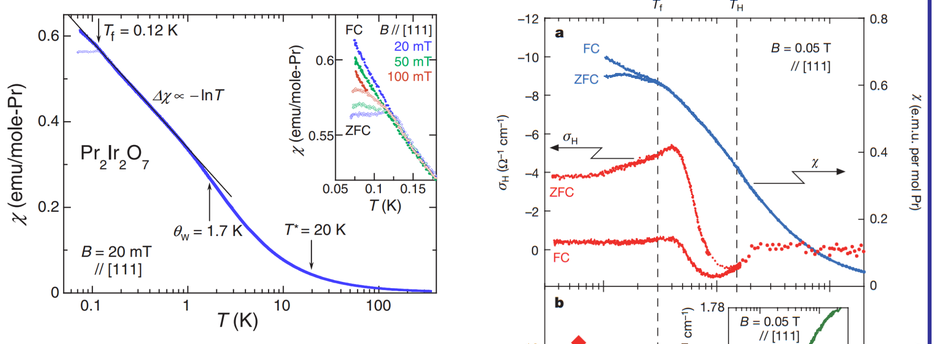
Nat. Mater. **13**, 356 (2014)



Chiral spin liquid

PRL **96**, 087204 (2006)

Nature **463**, 210 (2010)

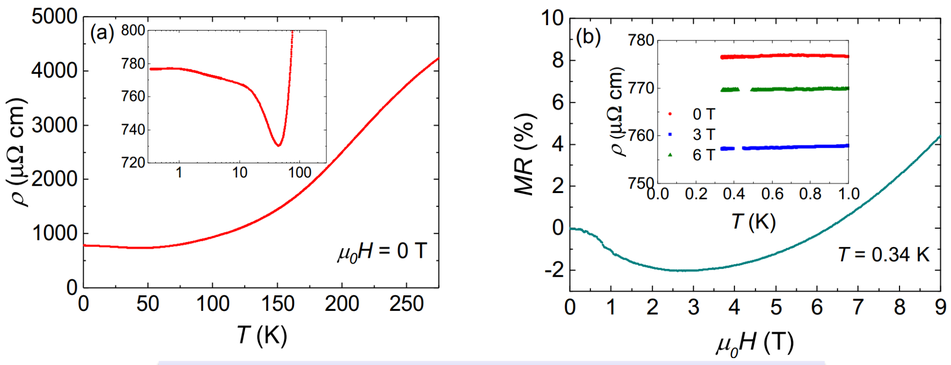


Motivation

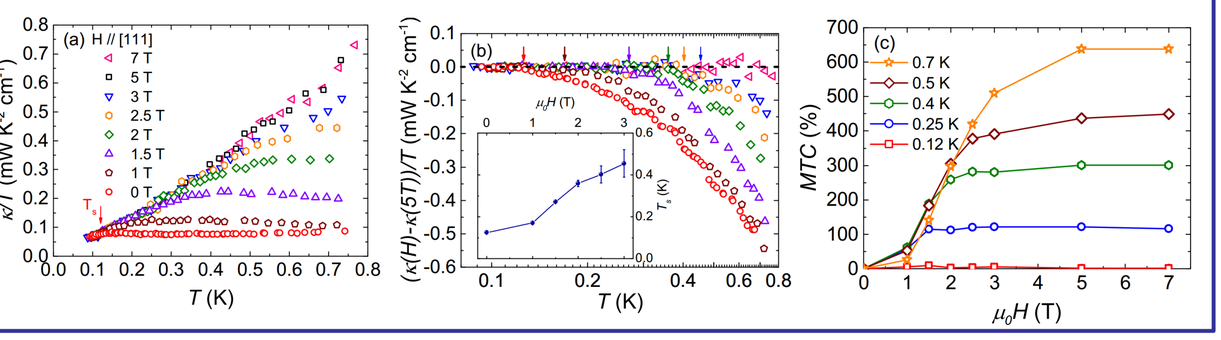
- Electrons at QCP?
- Magnetic excitations in spin liquid?

Charge and heat transport

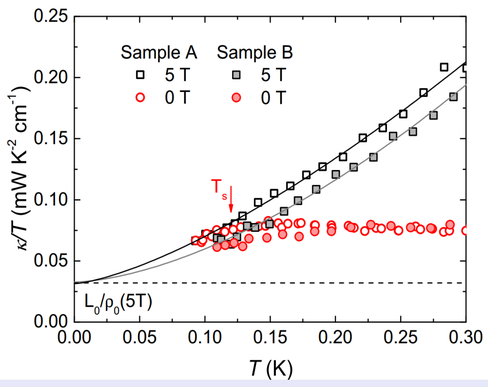
Kondo effect



Giant magneto-thermal conductivity



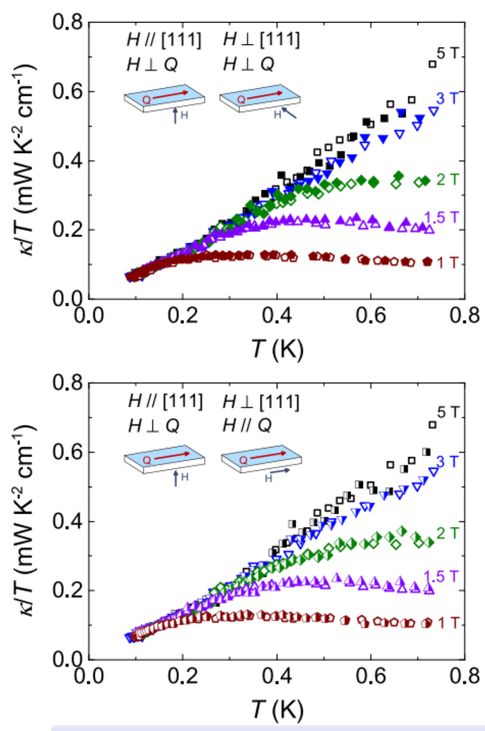
Verification of Wiedemann-Franz law



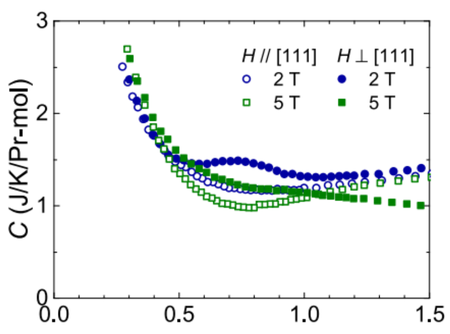
- Excluding the breakdown of electrons
- Incompatible with the Kondo breakdown QCP formalism
- Absence of fermionic magnetic excitations
- No positive contribution to κ from bosonic magnetic excitations

Giant isotropic MTC

Isotropic MTC



Anisotropic specific heat



Isotropic MTC & Anisotropic specific heat

↓

No negative contributions to κ from magnetic monopoles

↓

Scattering of phonons is unlikely from Ising dipole moments of Pr^{3+}

↓

Transverse fluctuations from quadrupole moments may paly an important role

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Quantum fluctuations melt classical spin ice states

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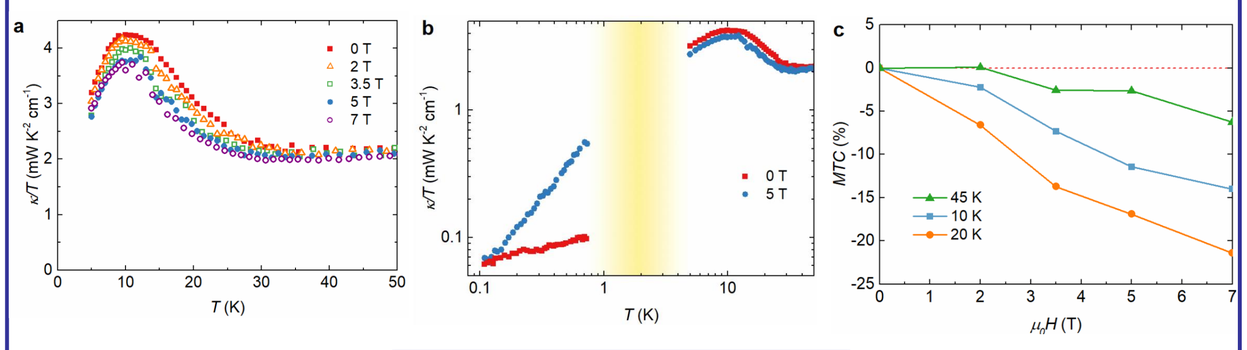
These results put its 4*f* moments in line with those in other Pr-based quantum spin ice candidates

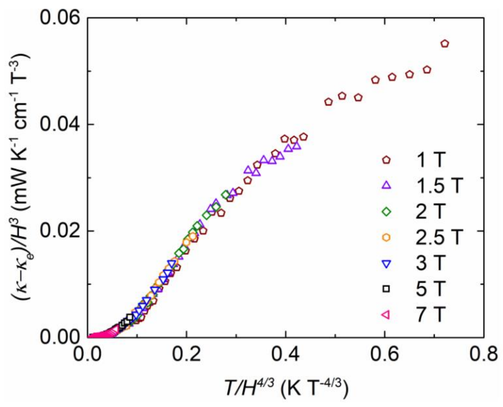
Crossover to negative MTC



Crossover region ~ θ_w = 1.7 K

- $T < \theta_w$, the underscreened moments form a correlated state
- $T > \theta_w$, the Kondo effect starts to lead to the screening of the 4*f* moments

Scaling of thermal conductivities



The scaling law is exactly the same as those in the magnetic Grüneisen ratio.

The complex *f-d* coupling between Pr moments and Ir electrons

Conclusions

- The Wiedemann-Franz law is verified at high fields and inferred at zero field, suggesting the normal behavior of electrons at the zero-field QCP and the absence of mobile fermionic magnetic excitations. This result puts strong constraints on the description of the quantum criticality in $Pr_2Ir_2O_7$.
- Neither positive nor negative contributions to k from bosonic magnetic excitations are found.
- A giant isotropic magneto-thermal conductivity is found at finite temperatures, indicating that the quadrupolar interactions and quantum fluctuations may play important roles.

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