# THERMAL TRANSPORT IN $U(Ru,Rh)_2Si_2$ AT THE "HIDDEN ORDER" TRANSITION

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The heavy fermion system $URu_2Si_2$ has remained a mystery for many years. This compound displays a very unusual transition at about 17 K [1]. Although first thought to be some form of magnetic phase transition, it was later discovered that this material possessed a very tiny magnetic moment, completely inconsistent with the large thermodynamic changes that occur. The origin of the "hidden" order has remained controversial to this day. Interestingly, at very high fields, this compound exhibits a strange form of quantum criticality as the HO phase is destroyed. We have recently investigated how this material transports heat through the 17 K "hidden order" transition in magnetic fields of up to 15 T.

We display our preliminary results for $U(Ru_{1-x},Rh_x)_2Si_2$ in Figure 1. As can be seen from the upper panel, the thermal conductivity of pure $URu_2Si_2$ single crystals shows a very large increase at the hidden order (HO) transition. As Rh is replaced for Ru, this peak is dramatically decreased. At a level of x=0.03 Rh doping, HO is actually completely suppressed, and a bona fide antiferromagnetic state is realized instead. Again, we see quite different behavior in the thermal conductivity in this doping regime as well, compared to the pure compound.

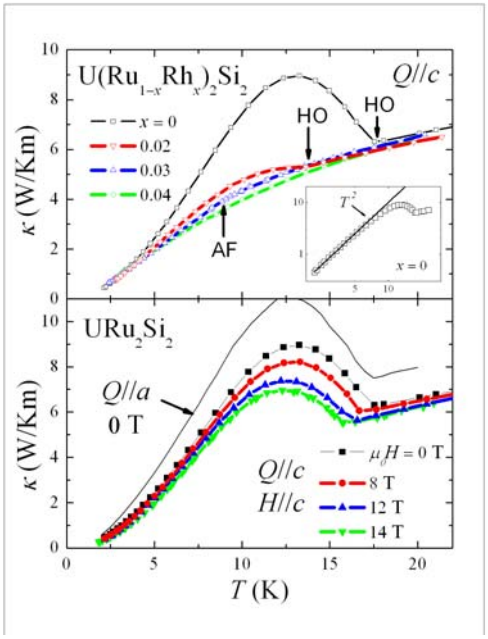


**Fig. 1.** *Upper panel: κ(T) for $U(Ru_{1-x},Rh_x)_2Si_2$. A dramatic increase in κ is observed at the "hidden order" transition, which is sharply suppressed with Rh doping at the Ru-site. Antiferromagnetic order is realized at x=0.03, with only a slight feature in κ. No phase transitions were observed at x=0.04. Lower panel: κ(T) of pure $URu_2Si_2$ with heat (Q) applied along the a-axis (dashed line) and the c-axis (closed squares). The H-dependence of the c-axis κ(T) is shown (closed symbols) up to 14 T, with H applied parallel to the c-axis. The enhancement of κ(T) at the HO transition is gradually suppressed with H.*

We also display in the lower panel of Figure 1, the magnetothermal conductivity of pure $URu_2Si_2$ for heat and magnetic field applied along the c-axis. As opposed to Rh doping, the effect of a magnetic field is much less pronounced on the large increase in κ.

From our preliminary results, we believe that this feature in κ is unique to $URu_2Si_2$, as compared to other antiferromagnetic heavy fermion materials. We have succeeded in explaining the changes in thermal conductivity for $URu_2Si_2$ at the Hidden Order transition with an itinerant BCS model. The applicability of the BCS model should serve as an important clue towards the theory of the Hidden Order. There may be an important connection between our discoveries and the proposed quadrupolar orbital ordering for the hidden order phase. Such orbital ordering should be strongly tied to the lattice properties of $URu_2Si_2$, of which the phonon thermal conductivity is one such probe. Large increases in κ are known in other materials, such as the charge-ordered manganites, for which orbital ordering is known to occur. At very high fields, this feature in $URu_2Si_2$ may serve as another indicator of the unusual "reentrance" of the hidden order in the quantum critical regime.

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## References

[1] Amitsuka, H., *et al*., J. Phys. Soc. Jpn., **69**, Suppl. A, 5 (2000).