Nernst effect and Kondo scattering in $(CeLa)Cu_2Si_2$

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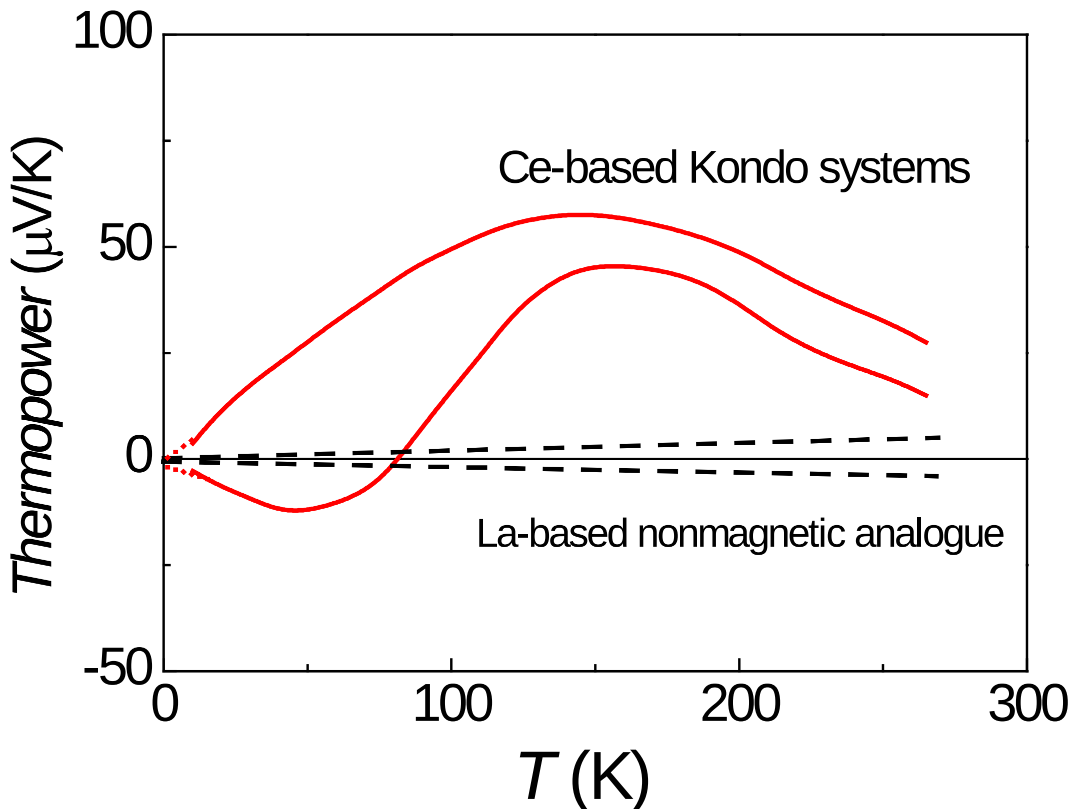
Heavy Fermion Physics: Perspective and Outlook, IOP-CAS Beijing, Jan 07-09, 2012

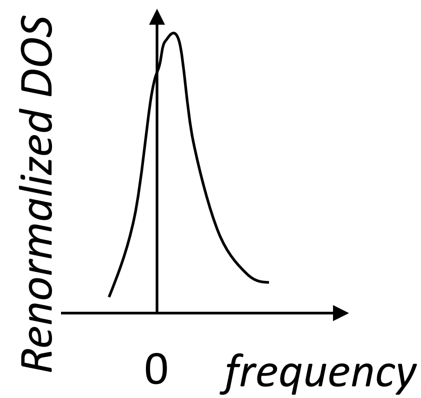
Outline

1. Introduction to magneto-thermoelectric transport of HF systems.
2. Nernst effect as a probe of relaxation time spectra and its relation to thermoelectric power.
3. Experimental results on (CeLa)Cu2Si2 and discussion.
4. Summary.

Introduction

Archetype TEP of Kondo systems



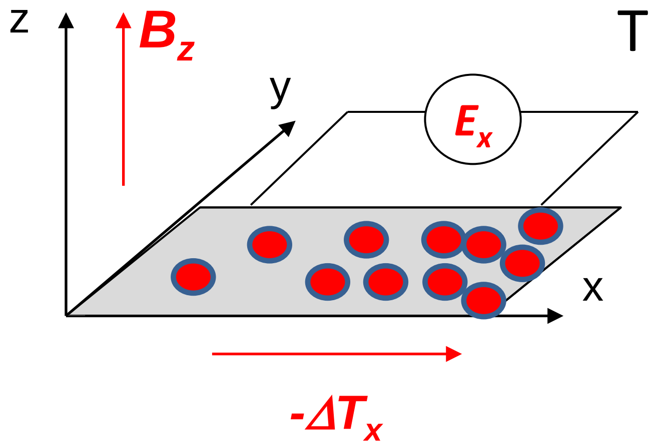


Typical Kondo resonance (Ce)

n-type quasiparticle, which seems inconsistent with TEP.

- Gradually adding Ce (or Yb) to a nonmagnetic matrix, the TEP responses following certain rules, *independent of the carrier type in the matrix.*
- *Open issues: microscopic reason for the different type of TEP(T); why carrier type of the nonmagnetic matrix not important…*

TE transport tensor in field

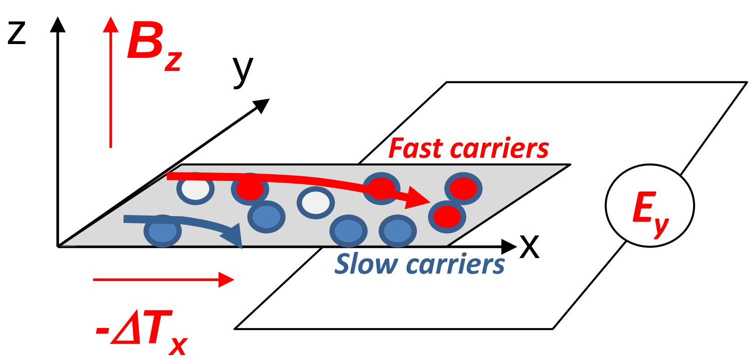


Thermoelectric power (diagonal S_{xx})

$S = E_x / |\triangle T|$

Origin: p/h asymmetric DOS and τ

Nernst coefficient (off diagonal S_{xy})



$$\nu = -E_y / B_z \left(\frac{\partial T}{\partial x} \right)$$

$$= E_y / B_z \, |\Delta T|$$

Origin: p/h asymmetric τ, band and scattering anisotropy, vortex dynamics…

Slow-diffusing carriers are more deflected by magnetic field than fast-diffusing carriers

Interplay between diagonal and offdiagonal TE component

$$Thermopower: \quad S_{xx} = -\frac{\pi^2}{3}\frac{k_B{}^2 T}{e}\frac{\partial \ln \sigma_{xx}}{\partial \varepsilon_F}$$

$$Nernst: \quad S_{xy} = -\frac{\pi^2}{3}\frac{k_B{}^2 T}{e}\frac{\partial \tan \theta_H}{\partial \varepsilon_F} \qquad (\text{Hall angle } \tan\theta_H = \frac{\sigma_{xy}}{\sigma_{xx}})$$

Important Assumptions:
1, Relaxation time approximation
2, relaxation time is the only E-dependent term in the Hall angle
3, measurements in low magnetic field

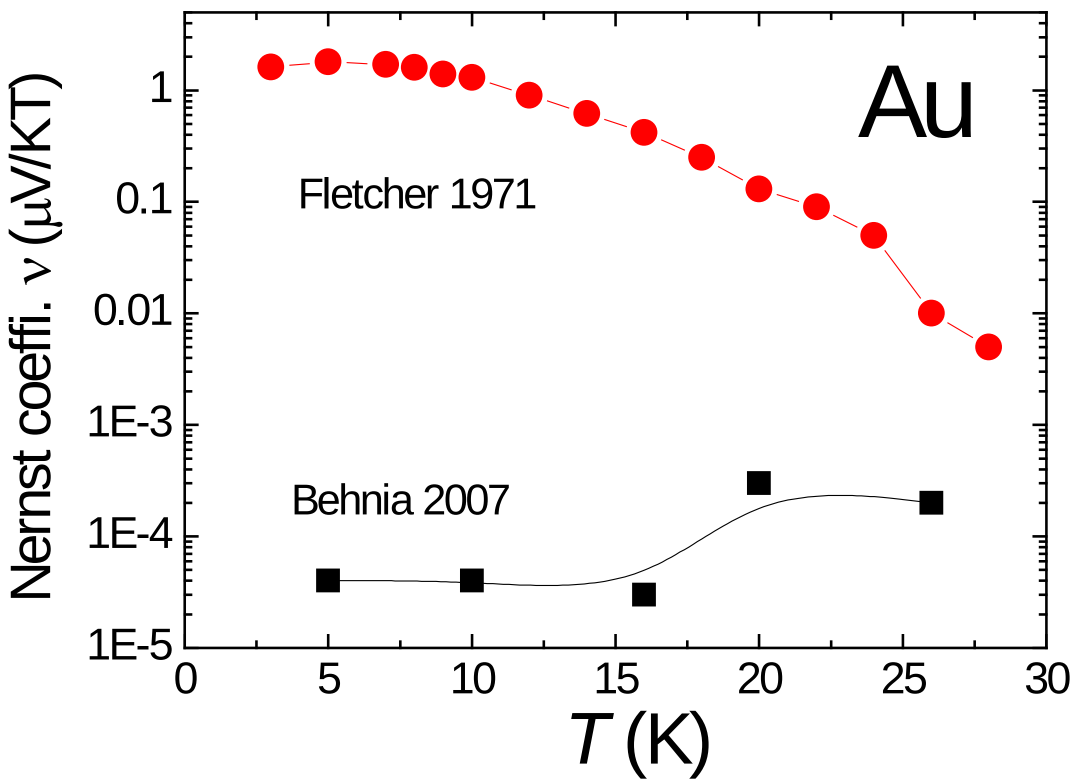
$$S(T) = \frac{\pi^2}{3}\frac{k^2 T}{e}\left[\frac{\partial \ln \sigma}{\partial \varepsilon}\right]_{\varepsilon=\varepsilon_F}$$

$$= \frac{\pi^2}{3}\frac{k^2 T}{e}\left[\frac{\partial \ln \tau}{\partial \varepsilon} + \frac{\partial \ln D}{\partial \varepsilon}\right]_{\varepsilon=\varepsilon_F}$$

$$S(T) = -\frac{\nu}{\mu_H} + \frac{\pi^2}{3}\frac{k^2 T}{e}\left[\frac{\partial \ln D}{\partial \varepsilon}\right]_{\varepsilon=\varepsilon_F}$$

In principle, Nernst measurement can disentangle the different sources of thermopower.

Compare two sets of Nernst data of gold

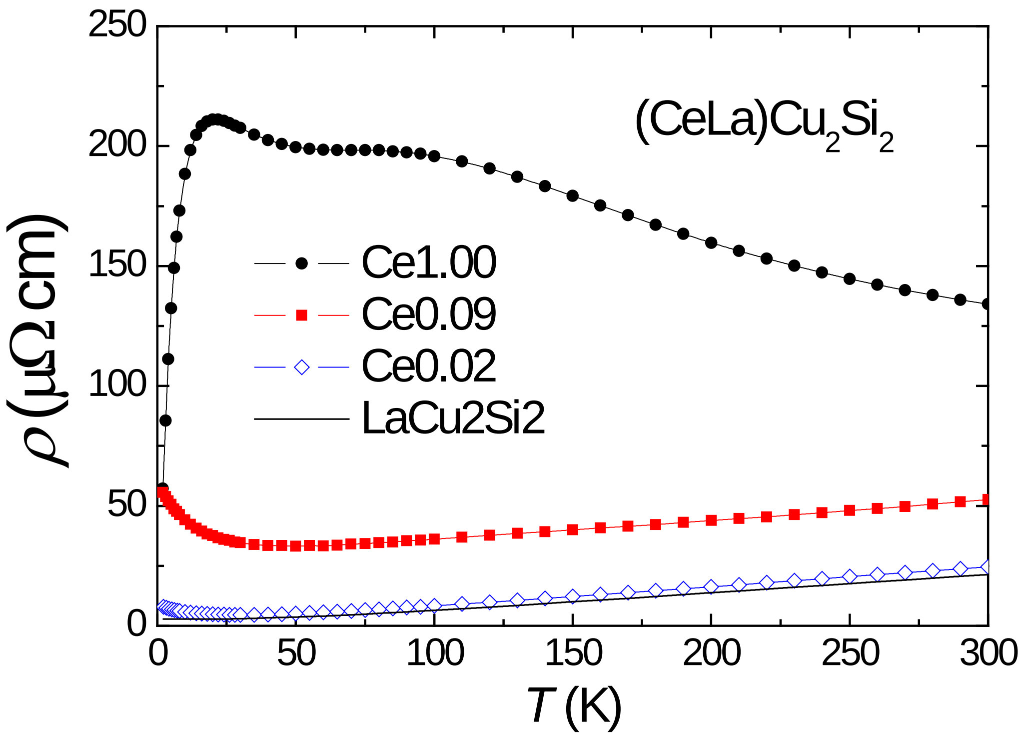


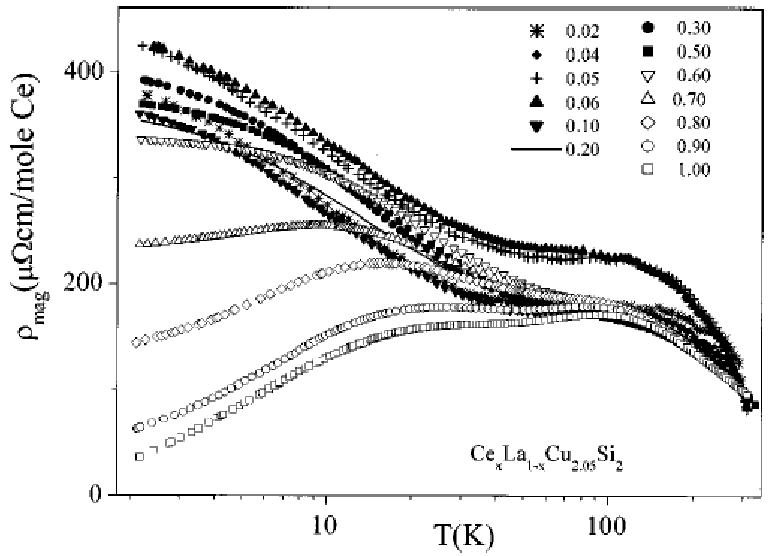
Several orders of magnitude different for gold of presumably different quality!

→Strong indication of Kondo scattering in Fletcher's results (dirty Au).

→Much more sensitive to unconventional scattering process than thermopower.

Resistivity of (CeLa)Cu2Si2



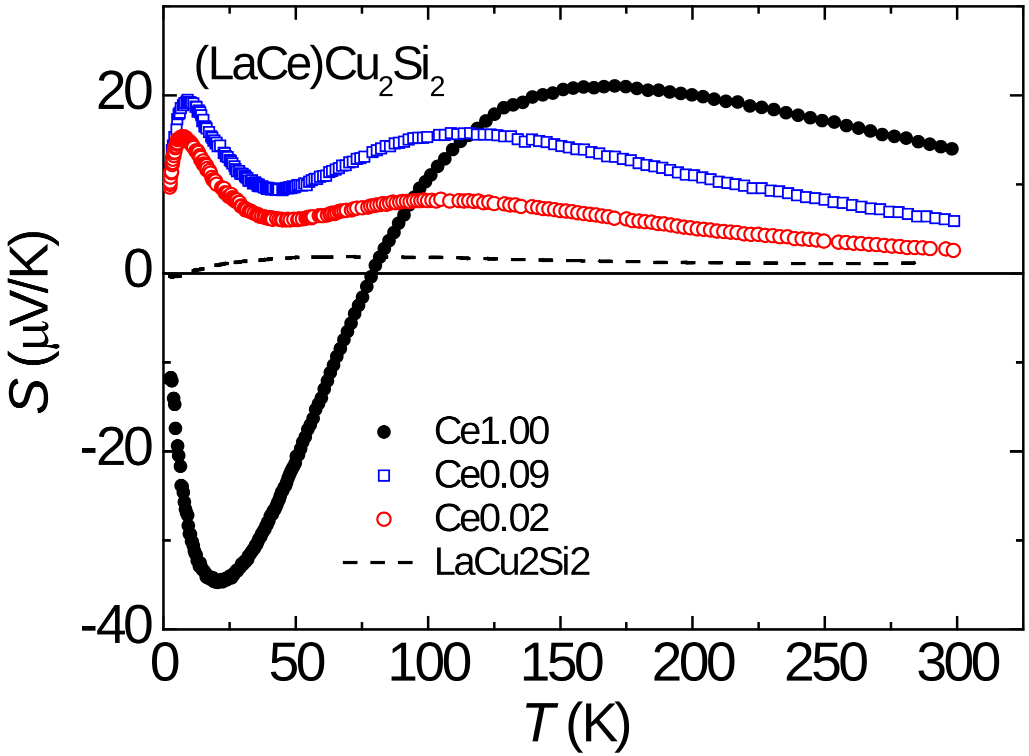


M. Ocko et al, 2001

x = 0.5: crossover from coherent to incoherent conduction

Interested: how Nernst signal evolves when coherence set in, where Kondo scattering is suppressed?

thermopower

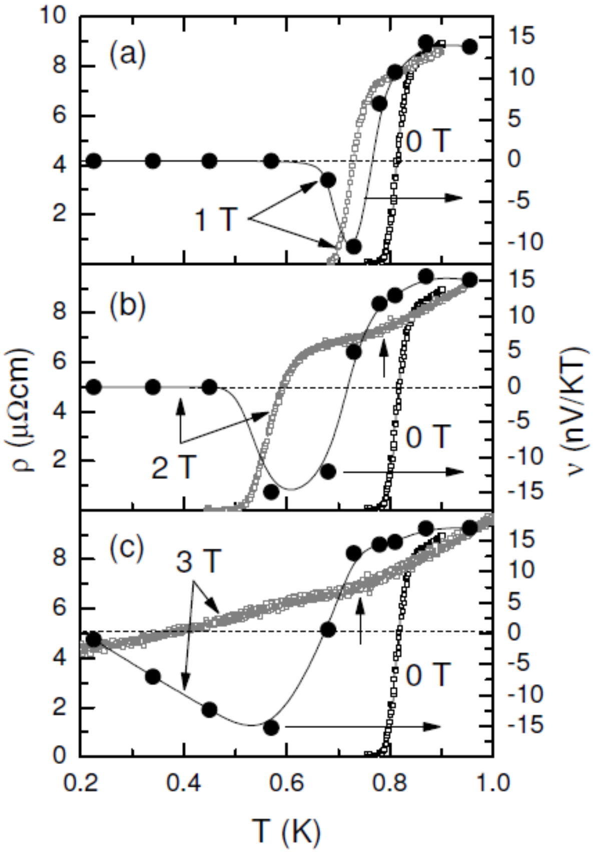


$$S(T) = \frac{\pi^2}{3}\frac{k^2 T}{e}\left[\frac{\partial \ln \sigma}{\partial \varepsilon}\right]_{\varepsilon=\varepsilon_F} = \frac{\pi^2}{3}\frac{k^2 T}{e}\left[\frac{\partial \ln \tau}{\partial \varepsilon} + \frac{\partial \ln D}{\partial \varepsilon}\right]_{\varepsilon=\varepsilon_F}$$

coherency

Also interested: does the very different low temperature (< 100K) thermopower of lattice (Ce1.00) and impurity (Ce0.02,Ce0.09) Kondo system indicate that the former is asymmetric –DOS driven, and the latter one is asymmetric-scattering-driven (coherency as the control parameter).

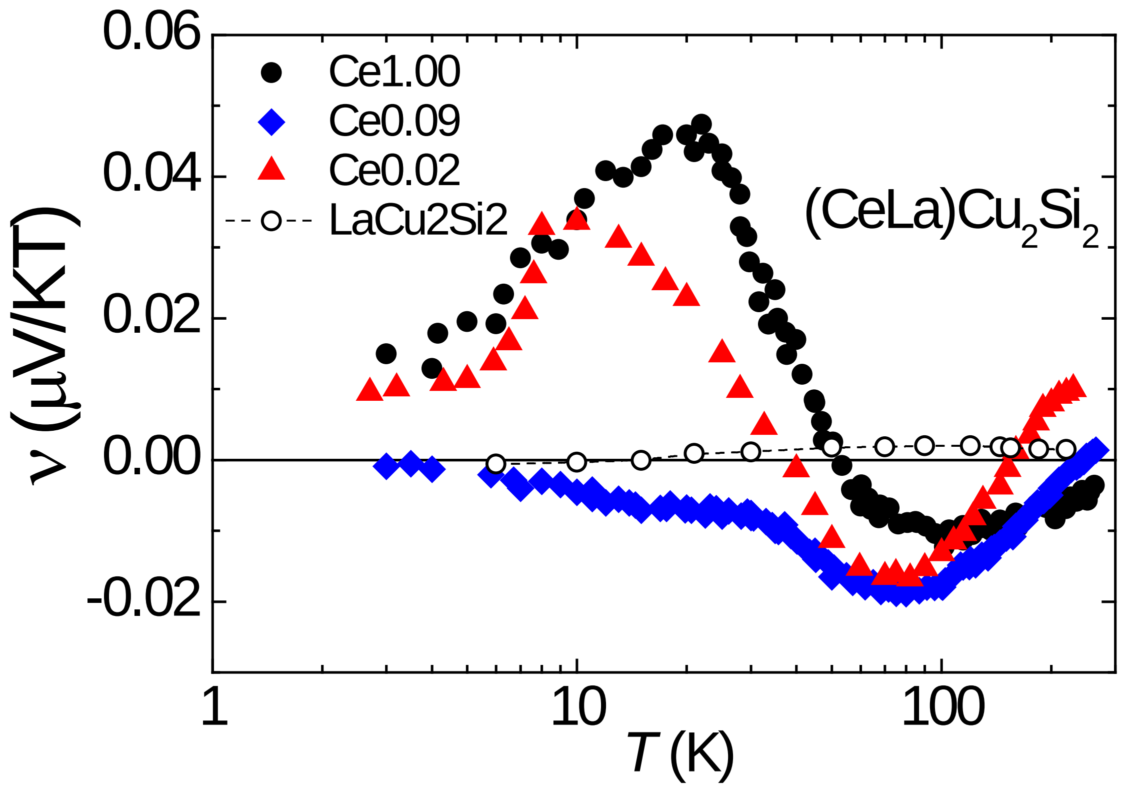
Nernst coefficients



Nernst effect in $CeCu_2Si_2$

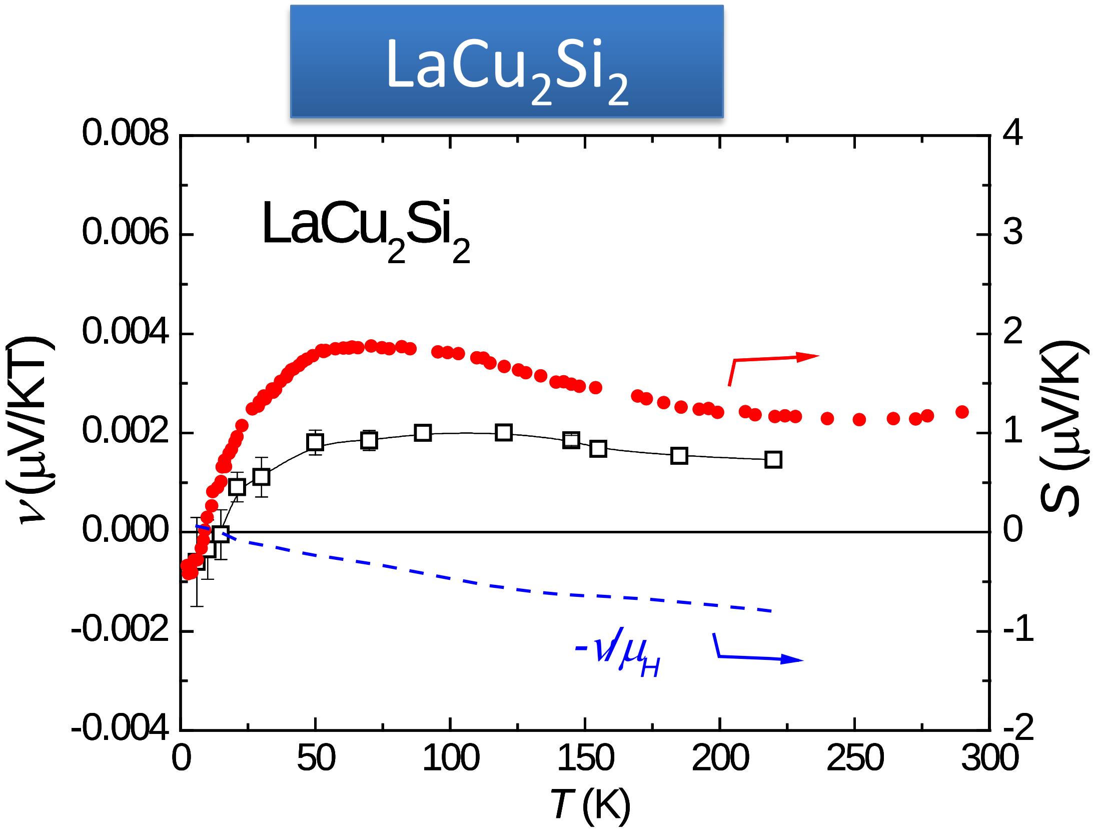
A-S Rüetschi, K Sengupta, G Seyfarth and D Jaccard

Journal of Physics: Conference Series **273** (2011) 012052



1. Nernst of LaCu2Si2 much smaller than Ce-based systems
2. Common feature for Ce compounds: high-T negative peak

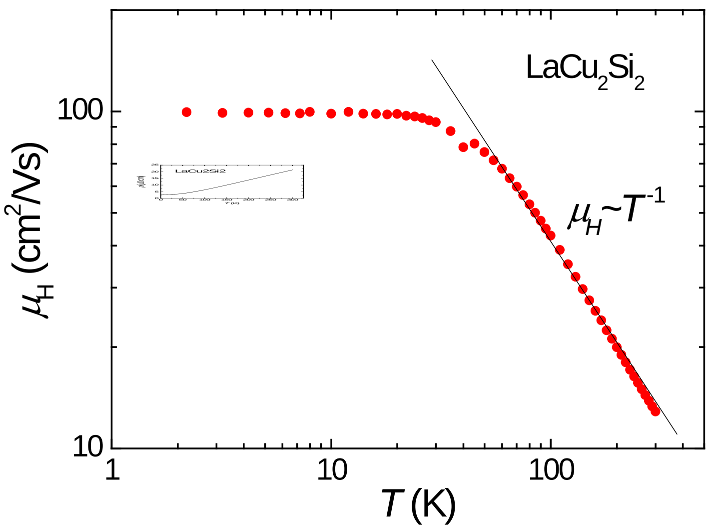
Nernst and thermopower: LaCu2Si2

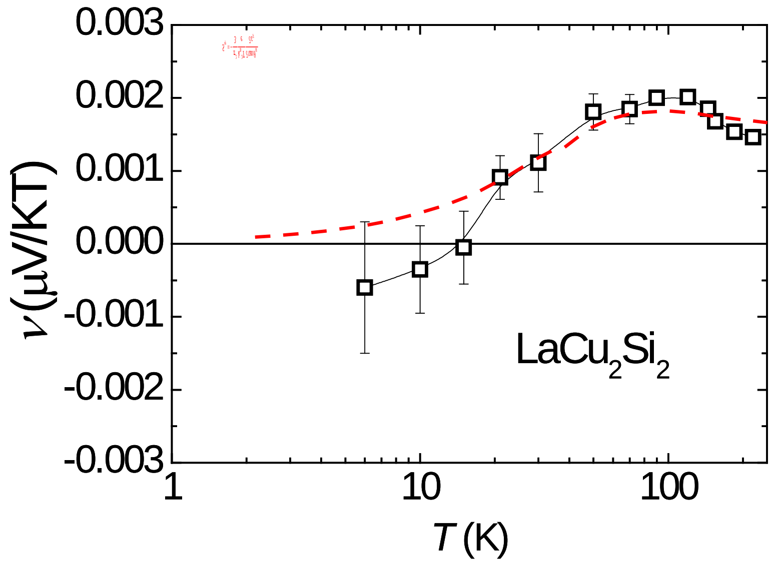


- ❑ **Thermopower dominated by DOS.**
- ❑ **Nernst signal dominated by scattering.**

→ S and Nernst coefficient are largely independent.

LaCu2Si2: approach from ac.ph. scattering





- Canonical resistivity and mobility
- Electron scattered by acoustic phonons

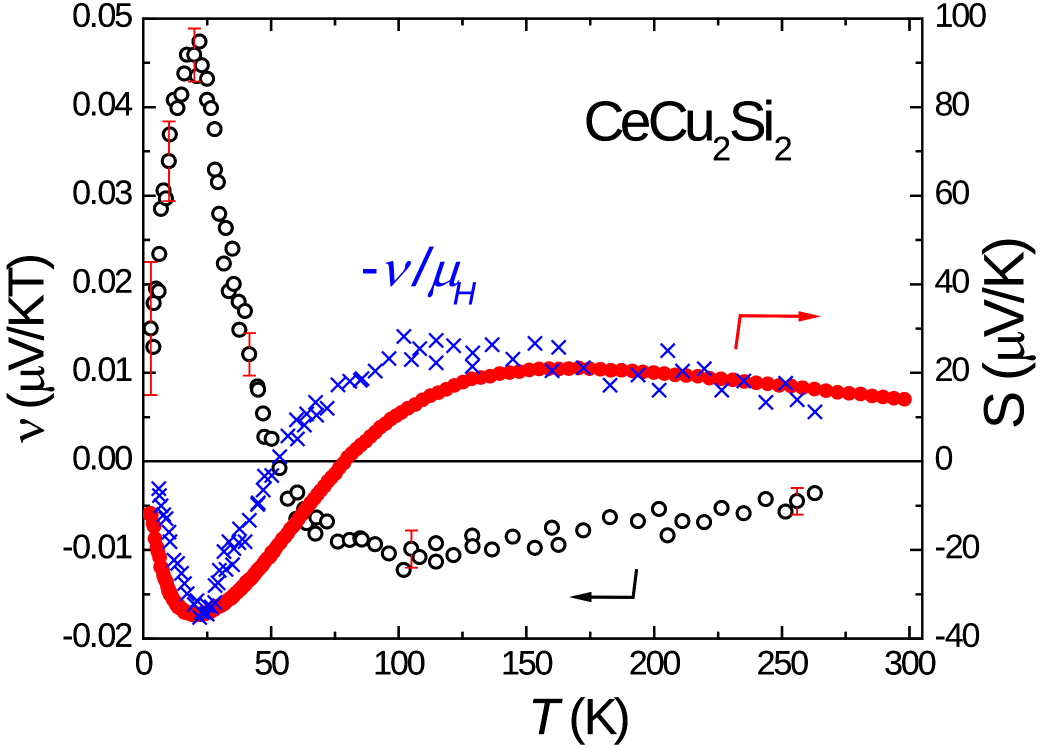
- Inputs: $\tau = \tau_0 \varepsilon^{-\frac{1}{2}}$

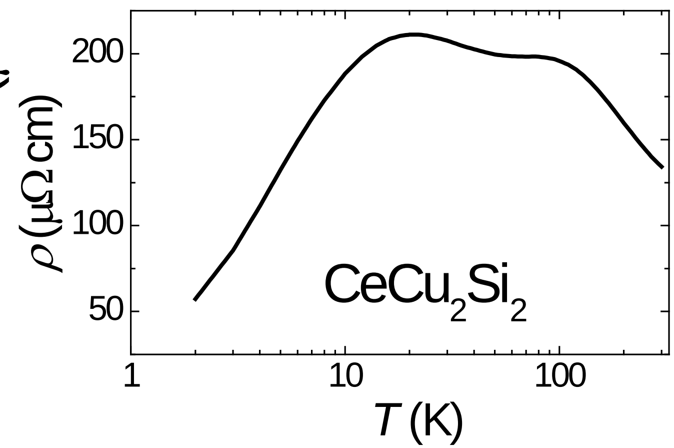
Acoustic phonon scattering:

Bare electron mass

Nernst and thermopower : CeCu2Si2

$CeCu_2Si_2$





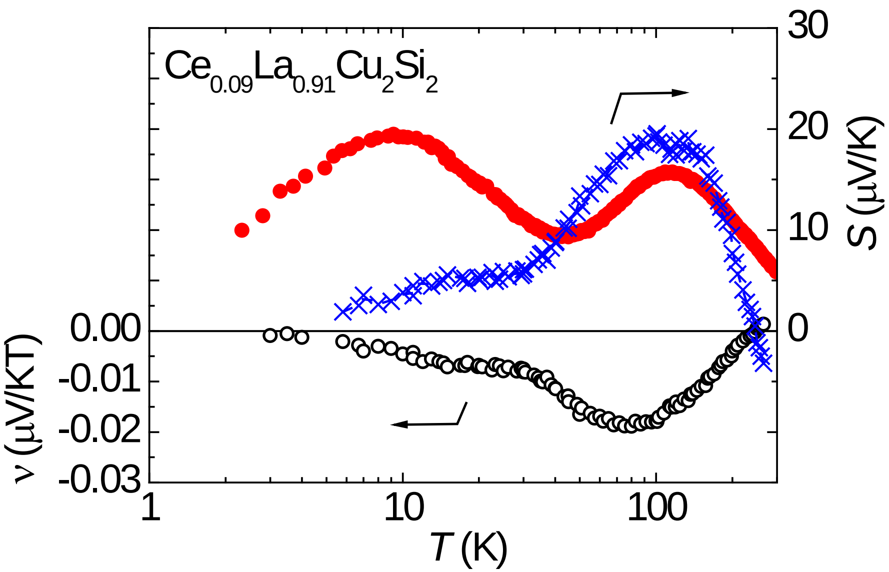
- ☐ Thermopower can be well traced by Nernst signal.

→ Asymmetric scattering rate (rather than f derived heavy band) leads to large S in the whole T range (2K -250K).

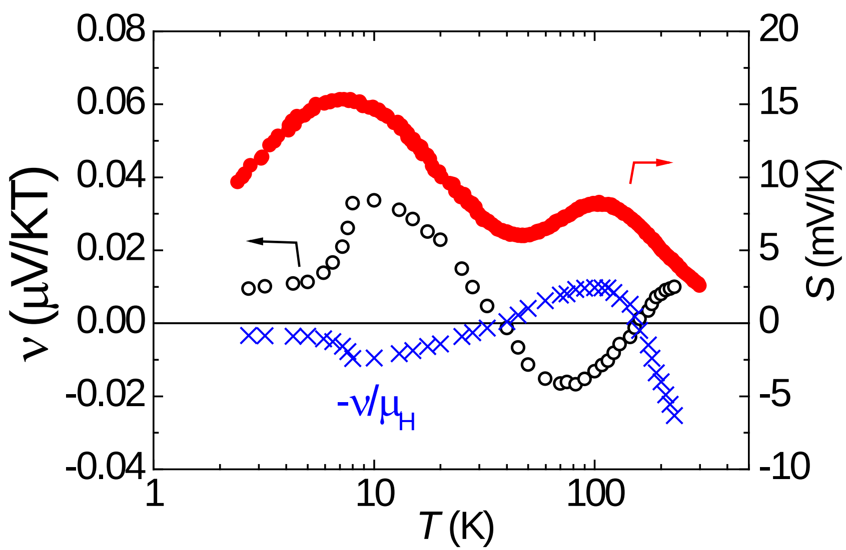
- ☐ No clear evidence of heavy-band formation down to 2 K.

Ce0.09- and Ce0.02-compounds

Ce0.09

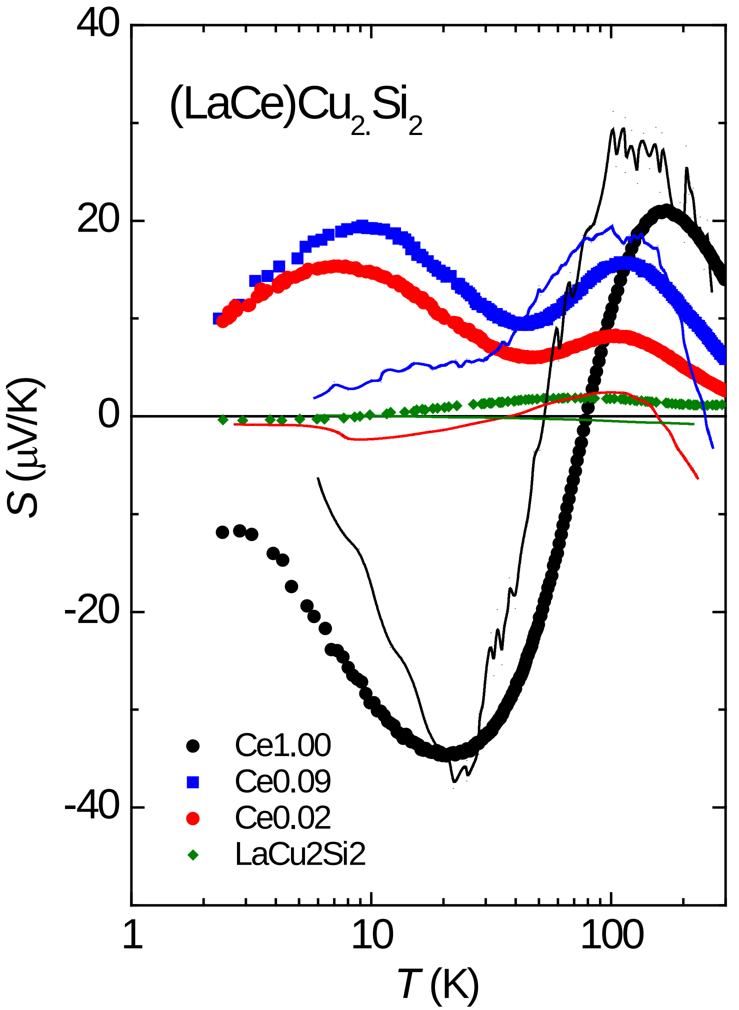


Ce0.02



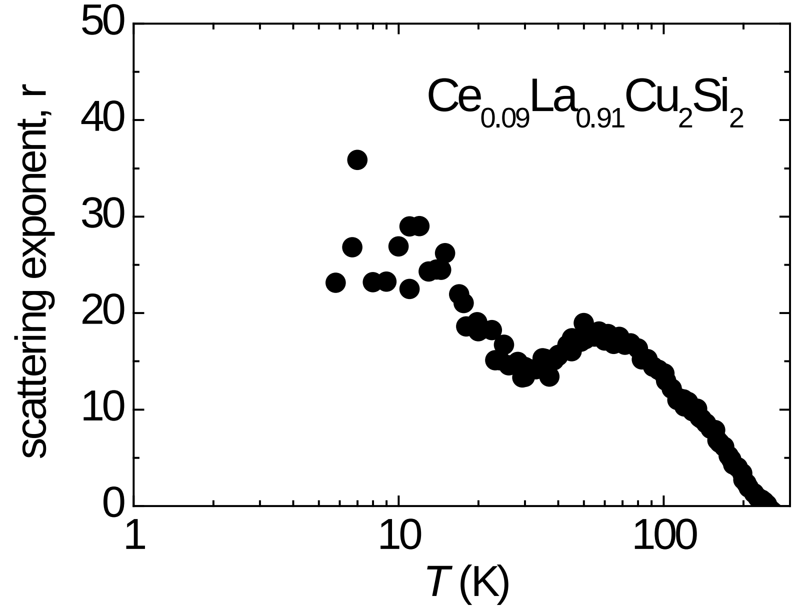
Surprise: Thermopower of Ce0.09 and Ce0.02 cannot be well reproduced by using Nernst signal ?

Measured thermopower vs. anticipation from scattering term



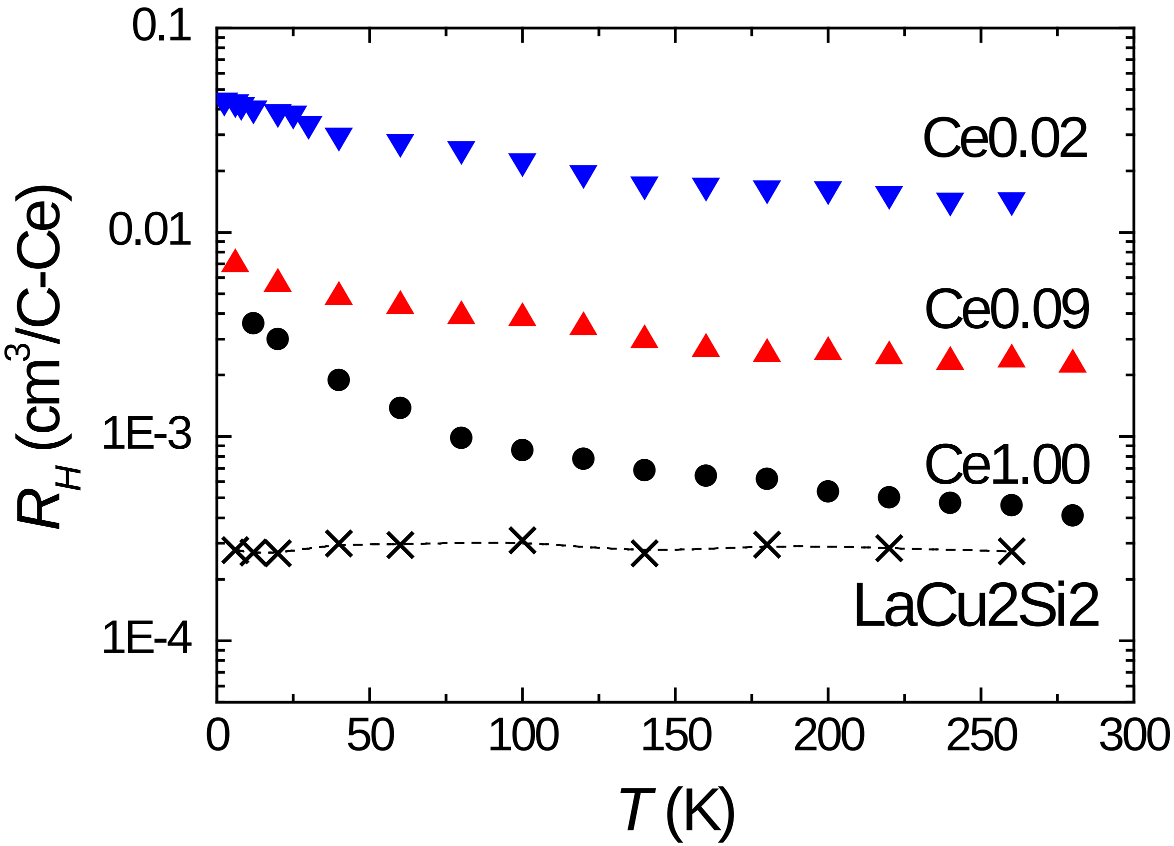
- Agreement worsens as Ce concentration decrease.

$$\tau = \tau_0 \varepsilon^r$$



Assuming validity of exponent law leads to extremely large exponent r!

Hall effect



→ R_H (normalized by Ce concentration) increases with decreasing Ce concentration.

→ Useful hint for understanding the anomalous Nernst effect, especially in the low Ce concentration side.

Summary

1. Like thermopower, Nernst coefficient in HFs is largely enhanced over a wide T range.

2. New insight concerning Kondo scattering can be obtained by Nernst measurement.

3. For $CeCu_2Si_2$, Kondo scattering seems able to fully account for its thermopower. While for its dilute systems, skew scattering contribution develops to Nernst signal, which can even mask the Kondo scattering contribution.

4. Systematic study on different Kondo systems desired.