Noncentrosymmetric Heavy-Fermion Superconductor $CeRhSi_3$

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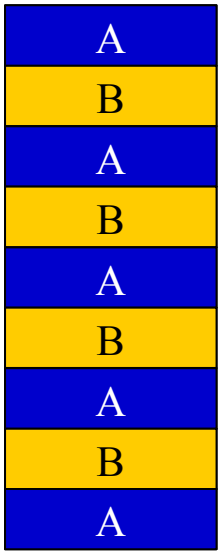
What is “non-centrosymmetric”?

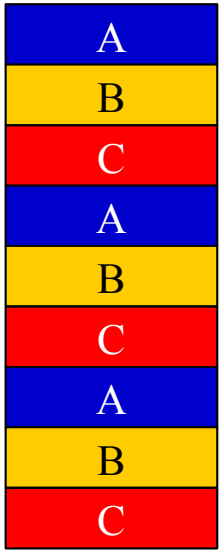
Noncentrosymmetric = broken inversion symmetry

Centrosymmetric



corresponding!

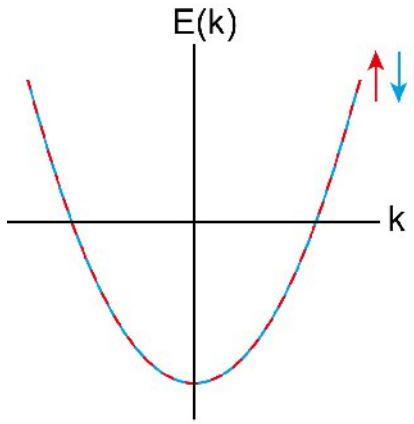
Noncentrosymmetric



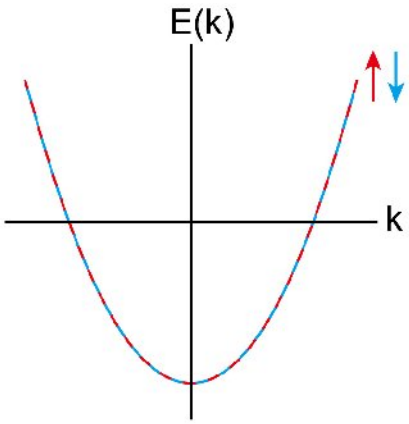
different!

Superconductivity in noncentrosymmetry

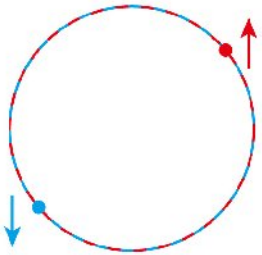
Centrosymmetric



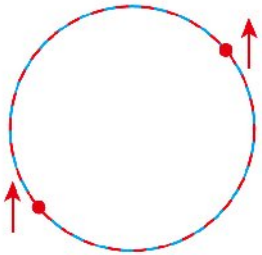
Singlet pairing



Triplet pairing



(k↑, -k↓)

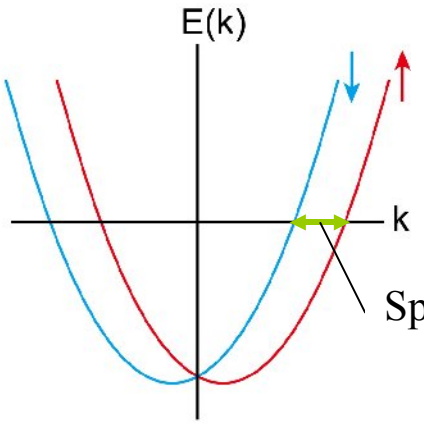


(k↑, -k↑)

s-wave: phonon
d-wave: AF mag.

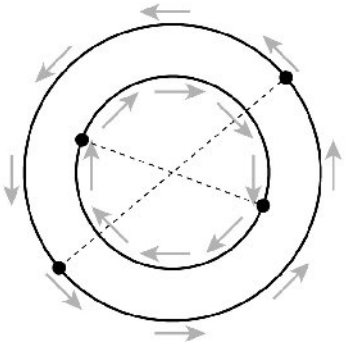
p-wave: F mag.

Nonentrosymmetric



Spin-orbit interaction

Admixture pairing

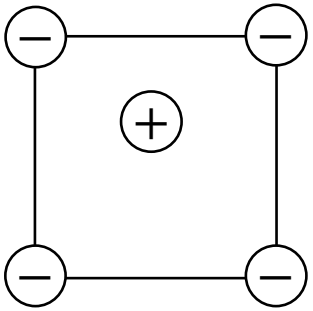


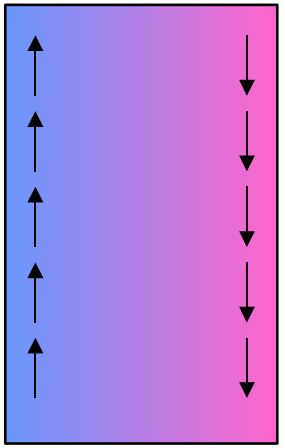
(kσ+, -kσ-)

New type!

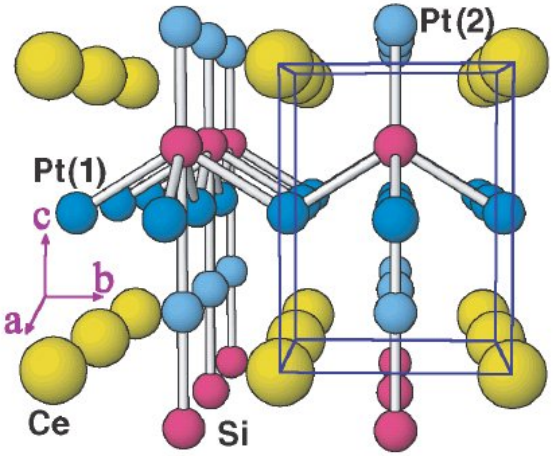
Physics based on a broken-inversion-symmetry

- Ferroelectricity (1920'-)
  - Piezoelectric phenomena
- Spintronics (1990'-)
  - Spin Hall effect
  - Spin injection
  - Spin transistors
- Noncentrosymmetric superconductivity
  - No dissipation spin current?
  - Other new phenomenon?



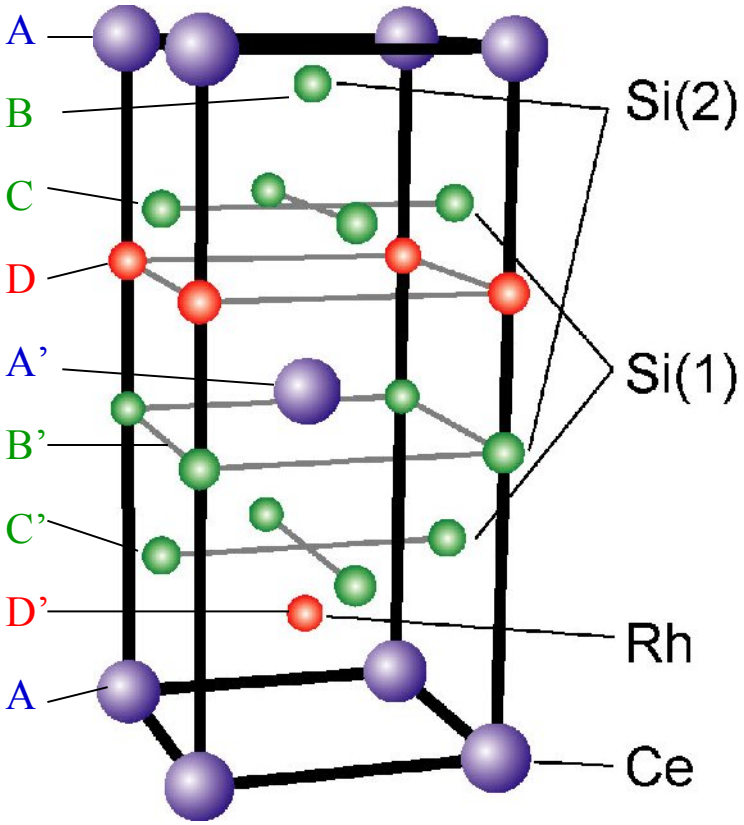


$CePt_3Si$ (Bauer, et al., PRL92(2004)027003)

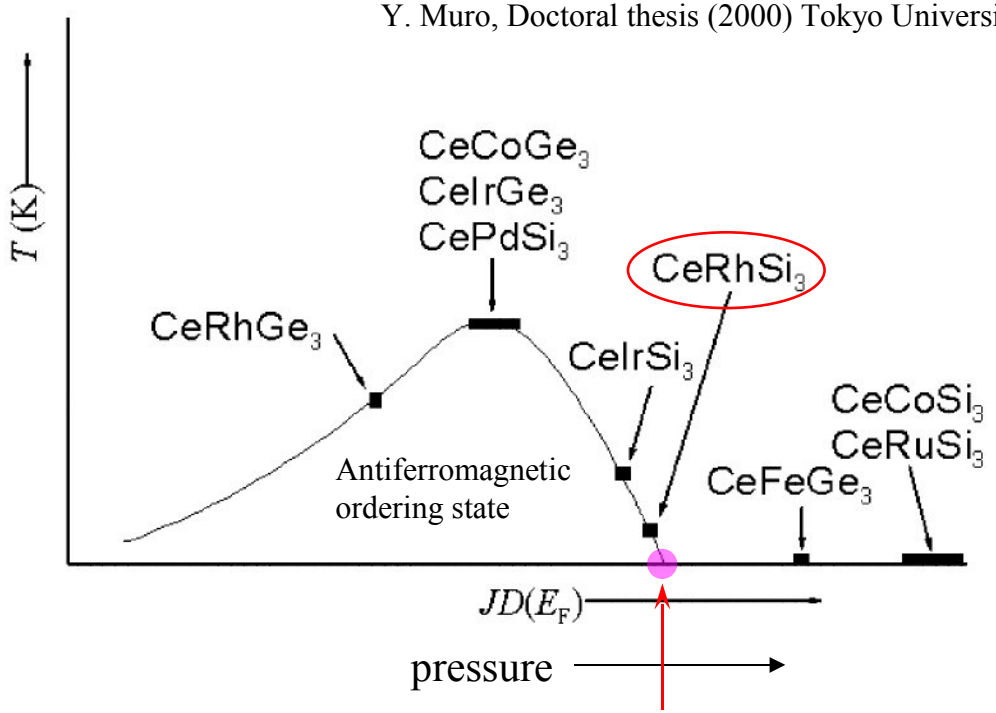


Noncentrosymmetric heavy-fermion antiferromagnet $CeRhSi_3$

$BaNiSn_3$-type tetragonal structure
Space group $I4mm$ (No.107)



Y. Muro, Doctoral thesis (2000) Tokyo University



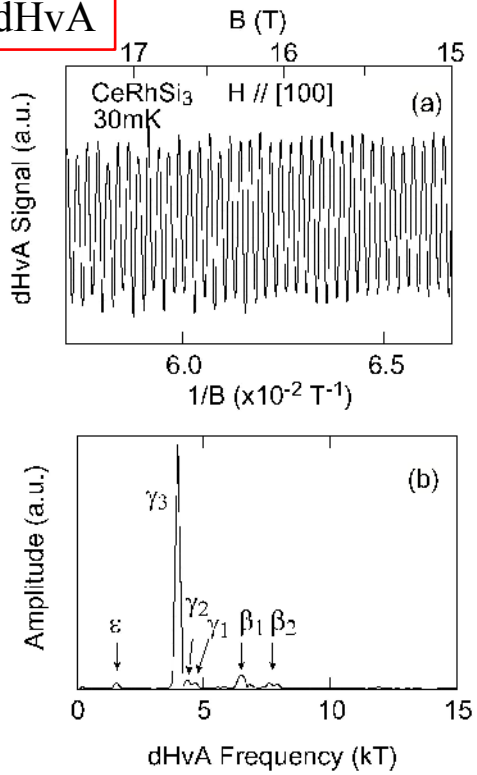
Unconventional superconductivity

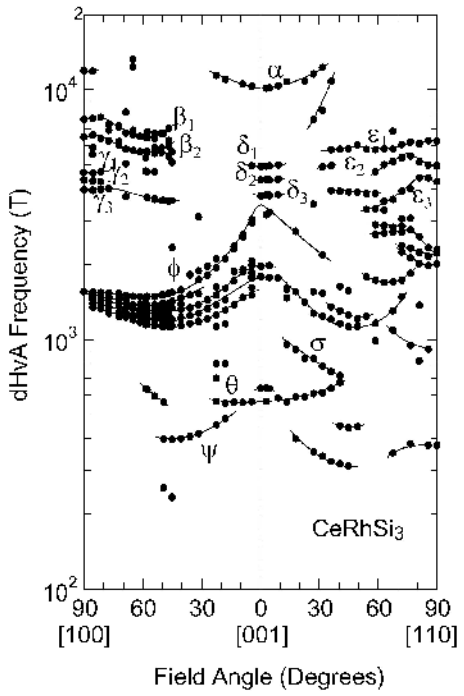
High-Quality Single Crystal $CeRhSi_3$

Crystal Growth

Ce:4N, Rh:3N, Si:5N
Czochralski method
900degs 1week

dHvA





Multiple branches due to SO interaction

$m^* \sim 25 m_0$ max

mean free path～2000Å

Experiments

Resistivity(J//[100])
Quality
Residual resistivity 0.42μΩcm
RRR＝180
AC-method

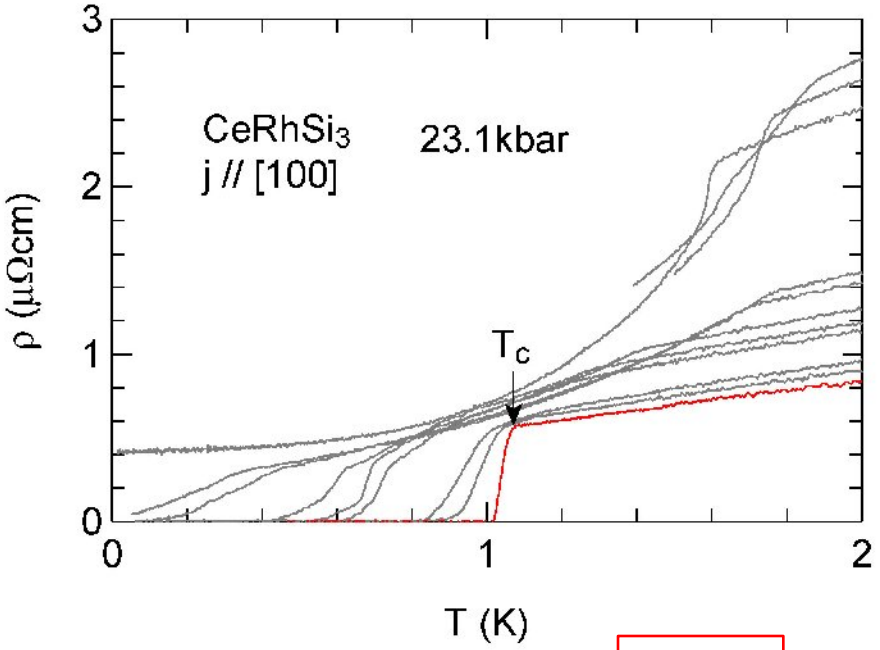
AC-susceptibility(H//[100])
RRR>100
138Hz、0.01Oe－0.1Oe
Absolute value of ac-χ is calibrated by SC of Sn with the same geometry.

Pressure
NiCrAl/Be-Cu piston cylinder cell
Medium: i- and n-propanol

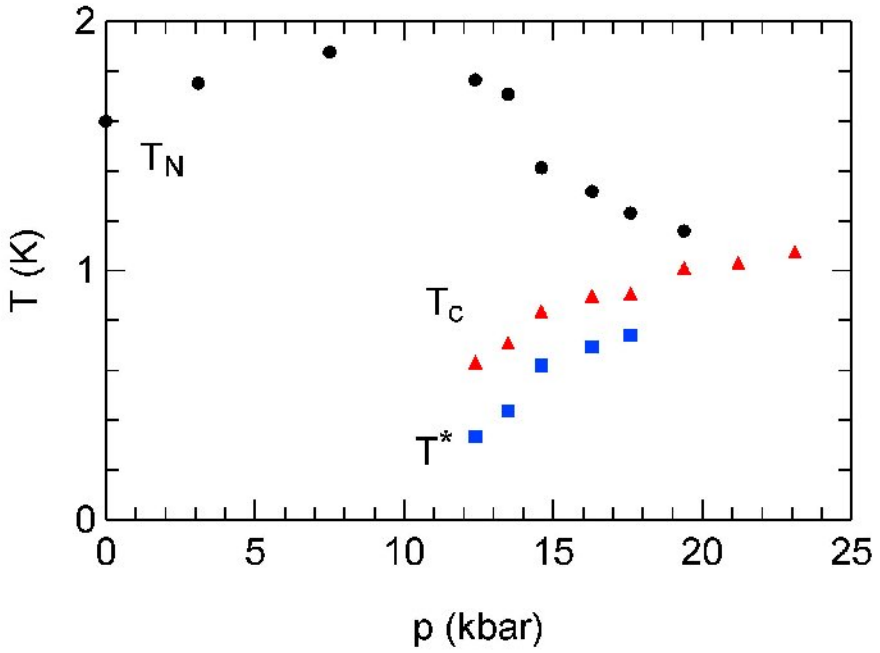
Kimura, et al., Physica B294-295 (2001)280.

ρ(T) for various pressures

ρ(T) for various pressures



T-p phase diagram



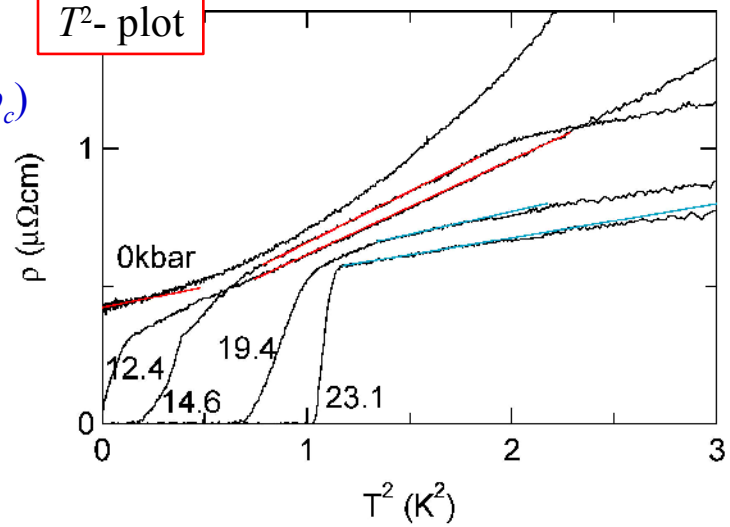
AFM vanishes at 20kbar(= p_c)

Zero-ρ in AFM

Broaden ρ-drop in AFM

Anomaly below T_c

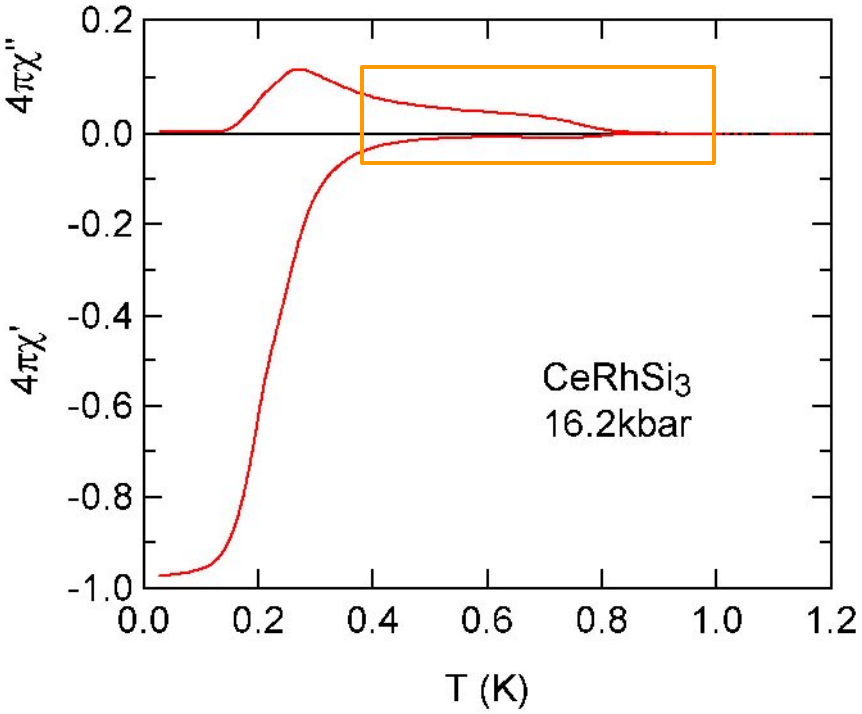
T^2- plot

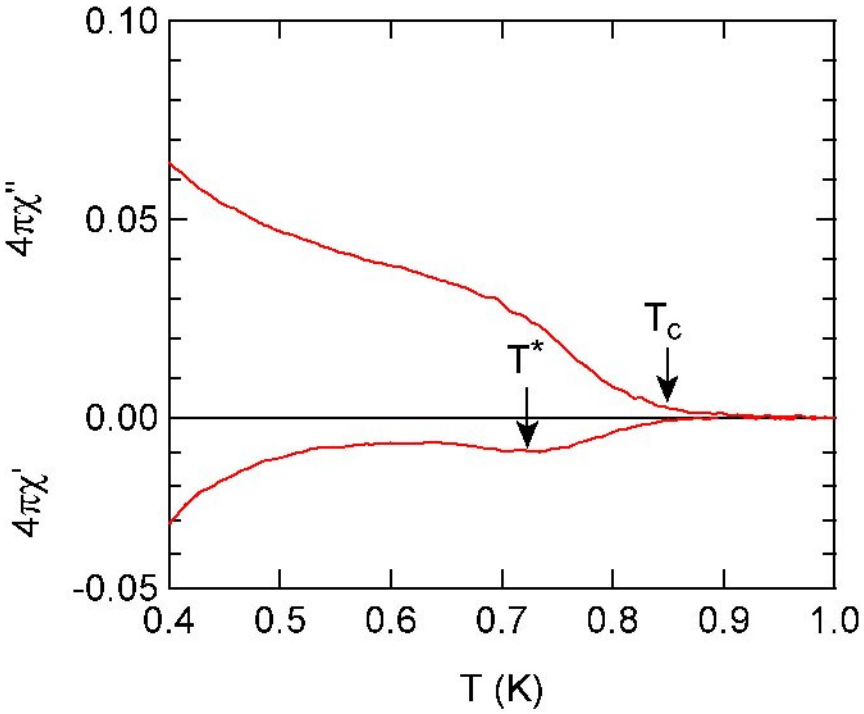


A increases with p

T-linear above p_c

ac–χ(T) for $p < p_c$





$4\pi\chi = -1 \rightarrow$ bulk SC (in AFM!)

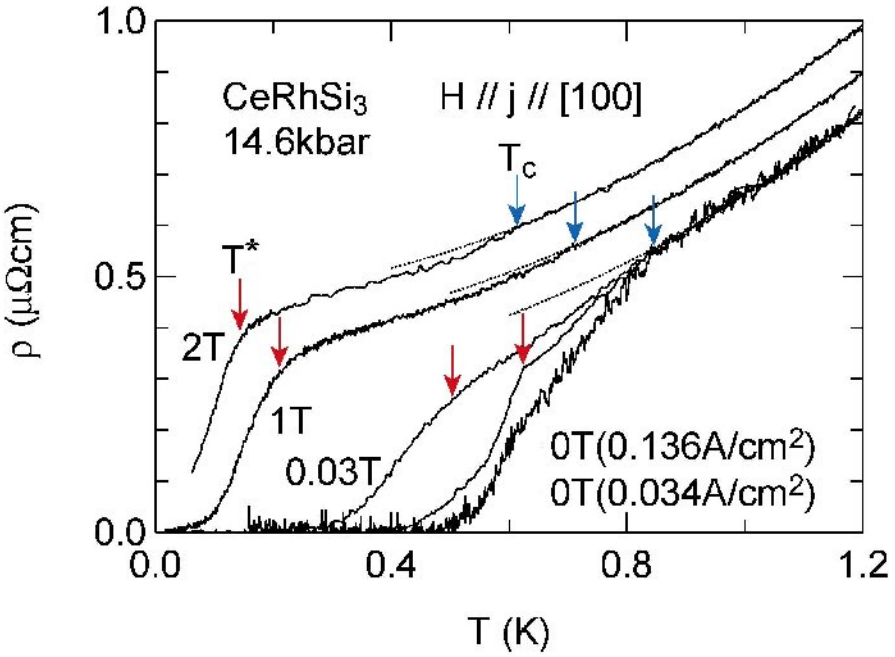
Large shielding far below T_{onset}

T_{onset}=0.85K(=T_c@ρ(T))

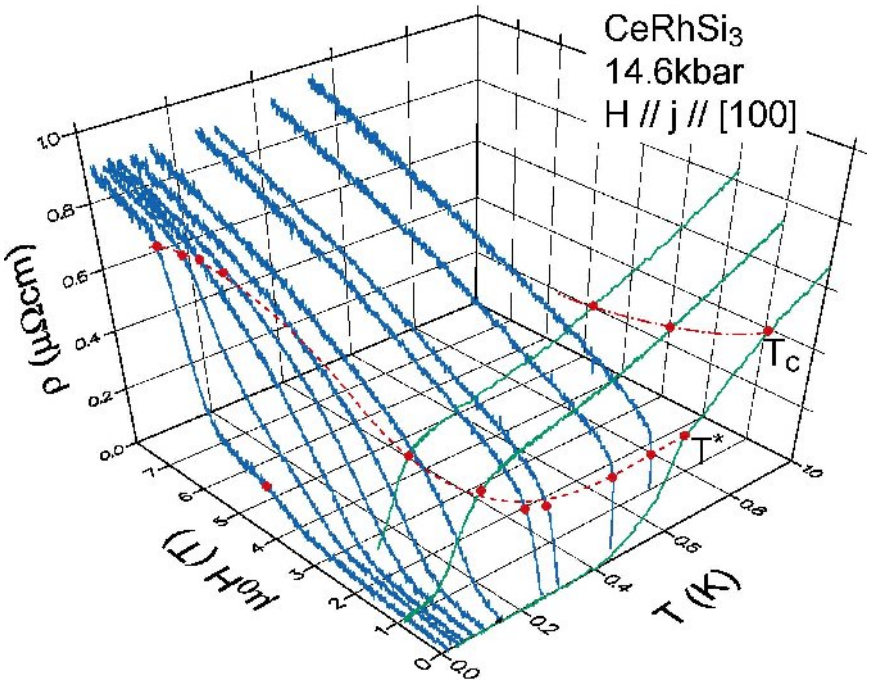
Small dip at T^*

Magnetoresistance for $p < p_c$

ρ(T) for various fields



3D plot



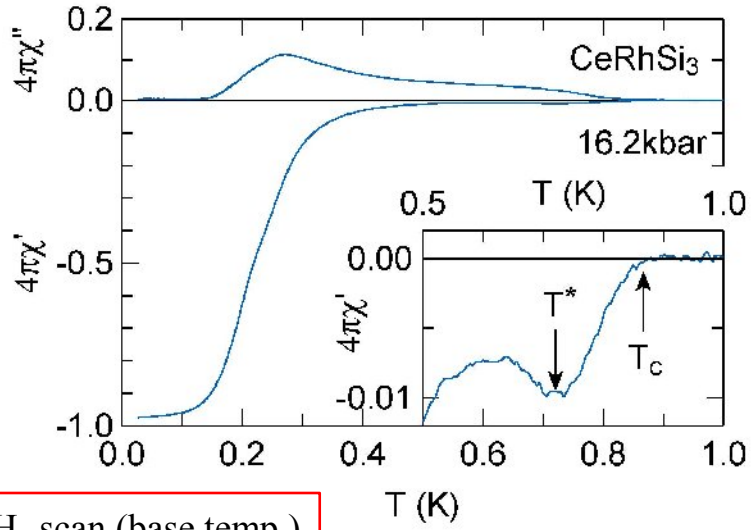
Resistive drop below T_c depends on j but T_c or T^* do not.

Transision at T_c becomes unclear with H.

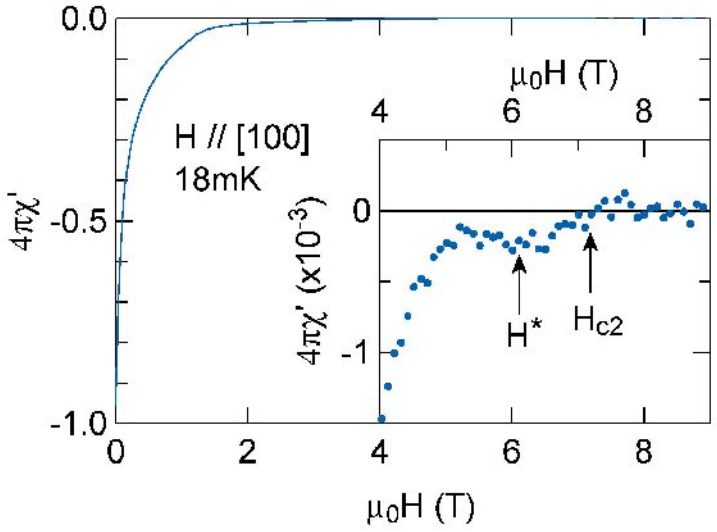
Large drop at T^*.

ac-χ(T) as a function of H for $p < p_c$

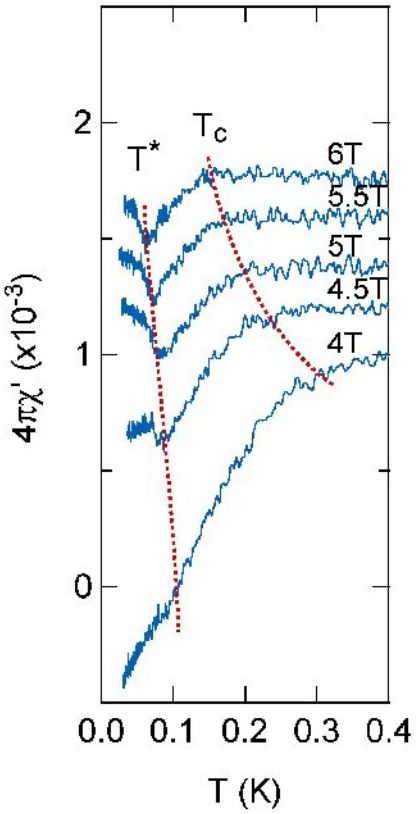
T- scan (H=0)



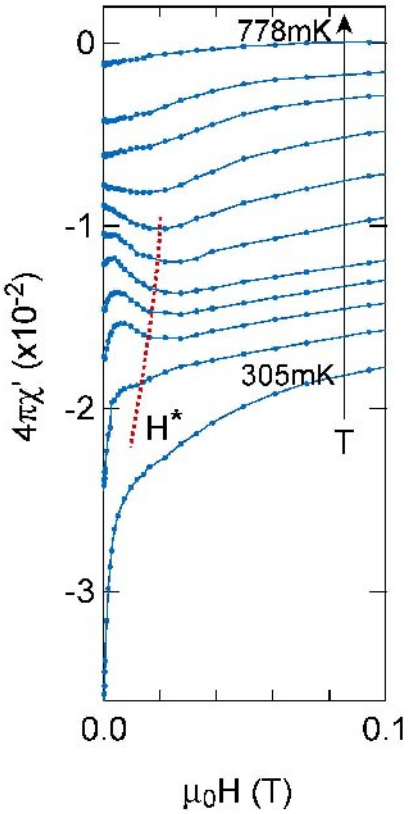
H- scan (base temp.)



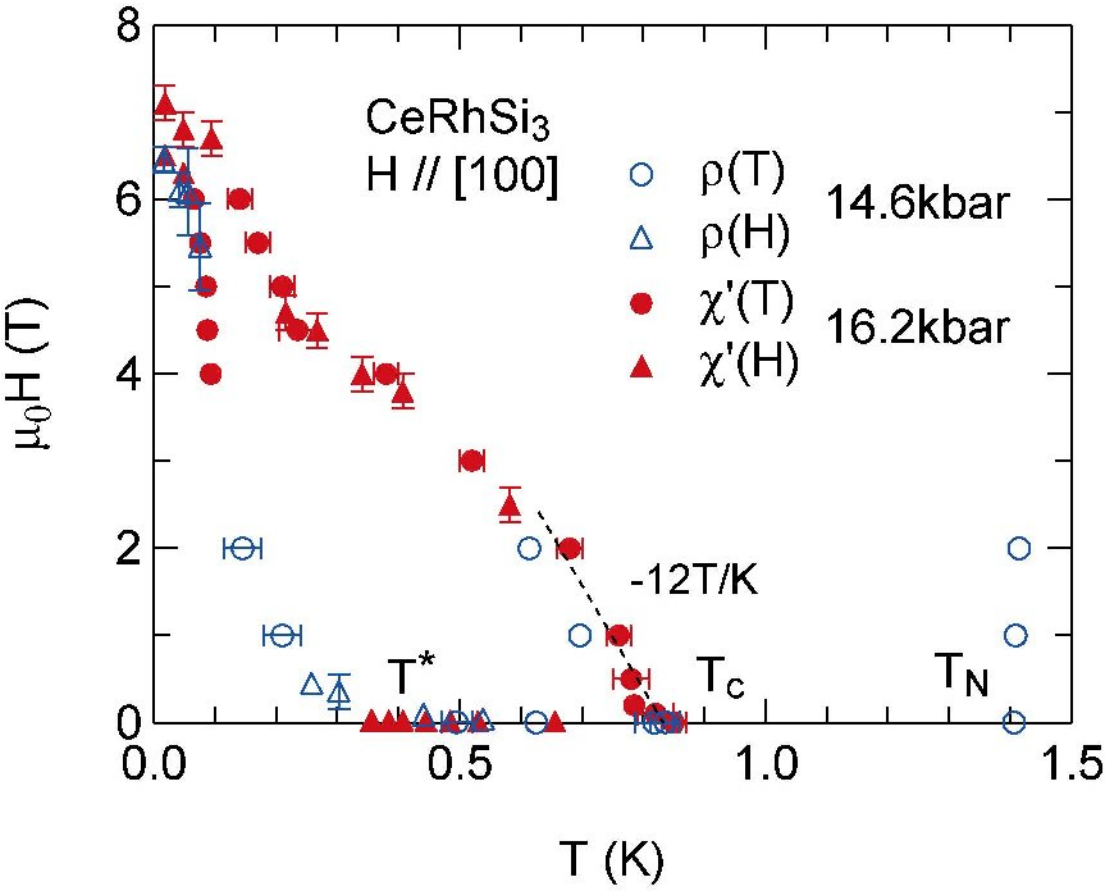
T- scan (in fields)



H- scan (const. T)



H-T phase diagram for $p < p_c$



H_{c2} (0)= 7T

ξ_0 = 70Å << l = 2000Å

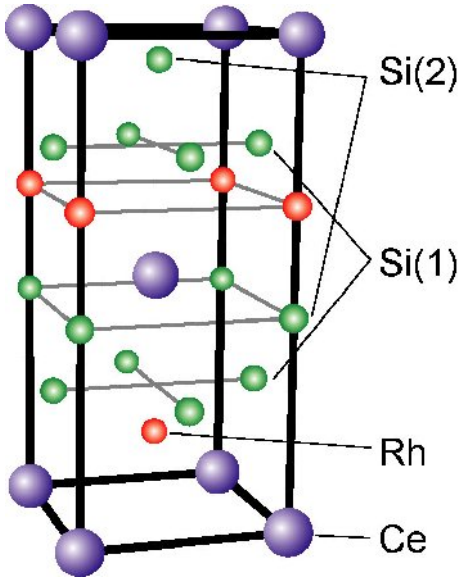
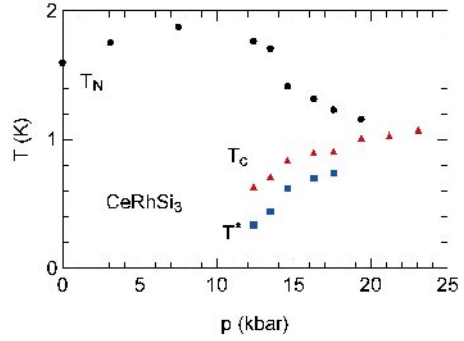
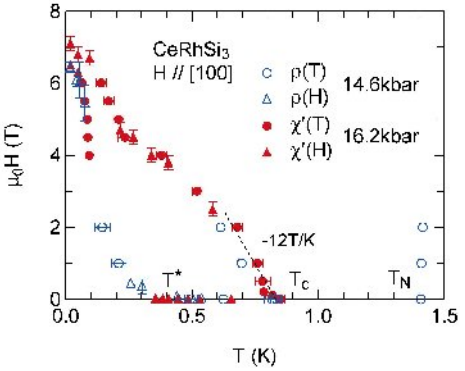
clean limit

dH_{c2}/dT = -12T/K

SC carried by heavy QP

Concave structure

Two phases?

Summary

- New noncentrosymmetric SC in HF antiferromagnet $CeRhSi_3$.
- Bulk SC in AFM state.
- Unconventional SC
  - High H_{c2} & dH_{c2}/dT
  - Strange phase diagram (concave structure, two phases?)