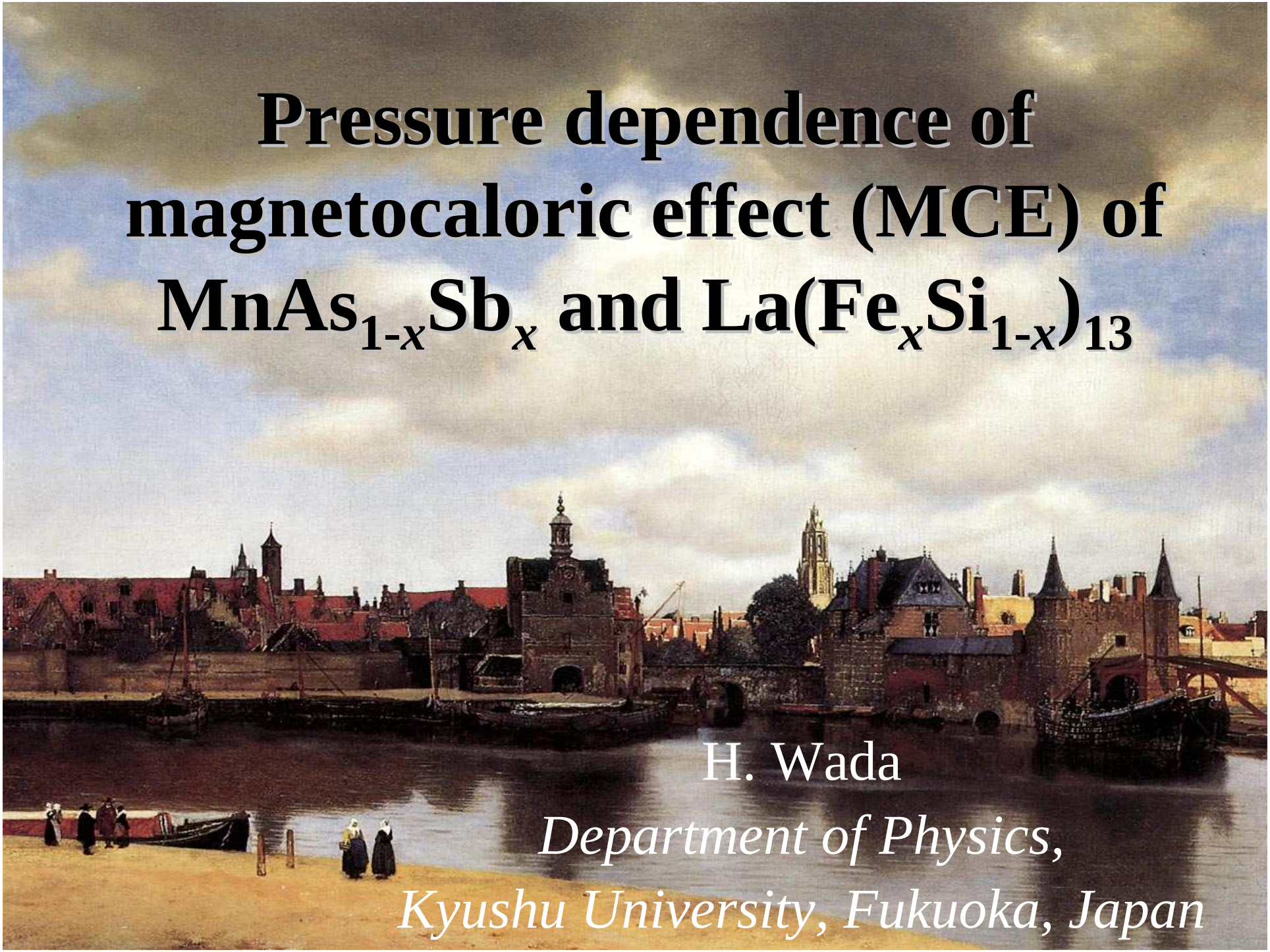
Pressure dependence of magnetocaloric effect (MCE) of $MnAs_{1-x}Sb_x$ and $La(Fe_xSi_{1-x})_{13}$

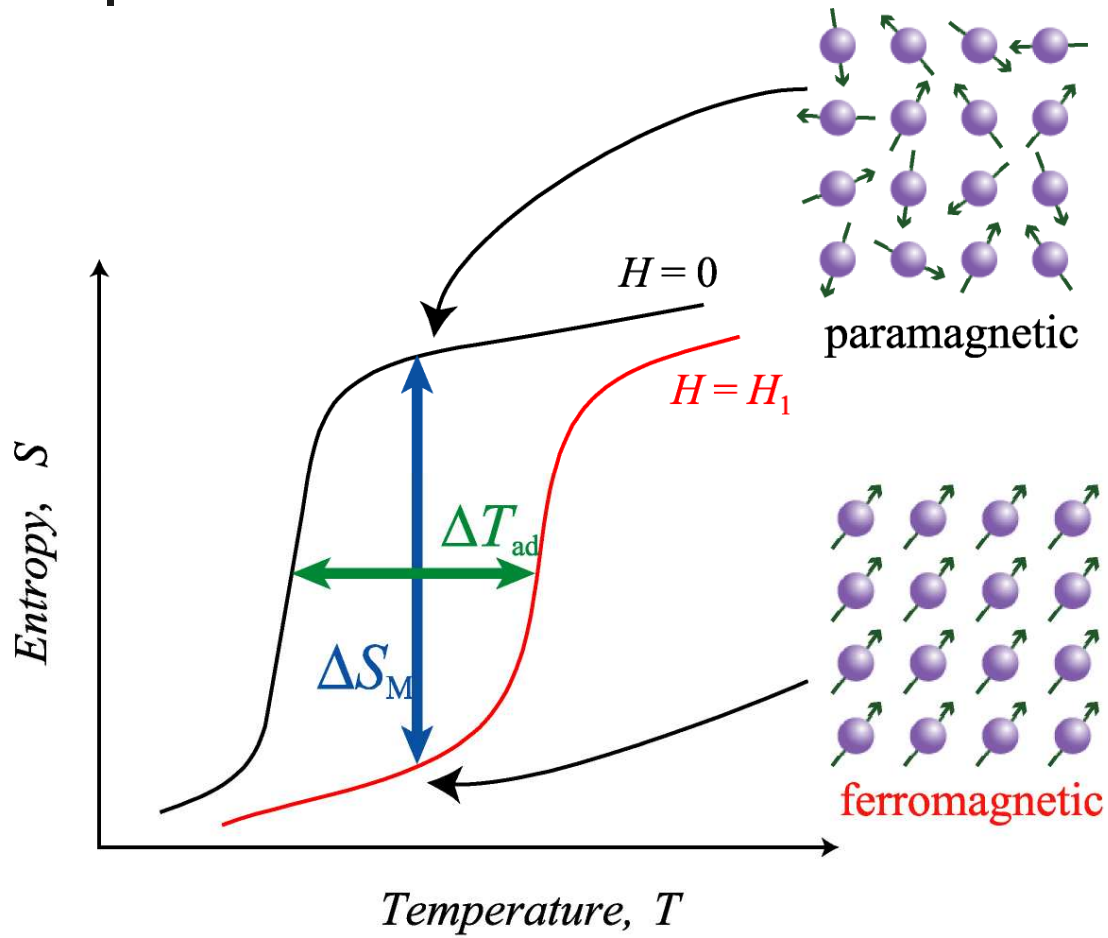


H. Wada

Department of Physics,

Kyushu University, Fukuoka, Japan

MCE of a first-order magnetic transition (FOMT) system



$Gd_5Si_2Ge_2$

$MnFeAs_{1-x}P_x$

$MnAs_{1-x}Sb_x$

$La(Fe_{1-x}Si_x)_{13}$

$CoMnSi_{1-x}Ge_x$

Ni_2MnGe etc.

Advantages and disadvantages of FOMT systems

Advantages

- Giant or large MCE in a weak magnetic field.
- Most of materials are transition metal based compounds.

Disadvantages

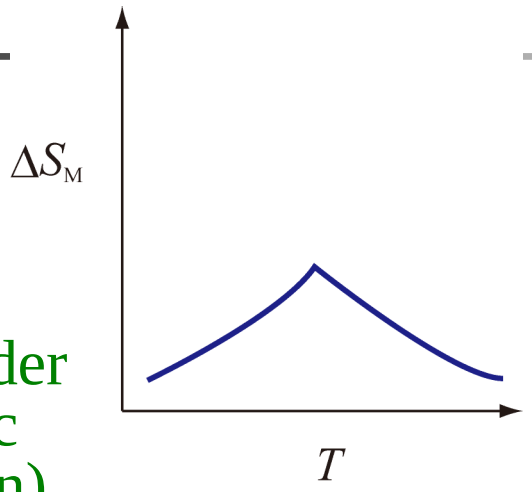
- MCE is limited in a narrow temperature range.
- Additional properties are not favorable.

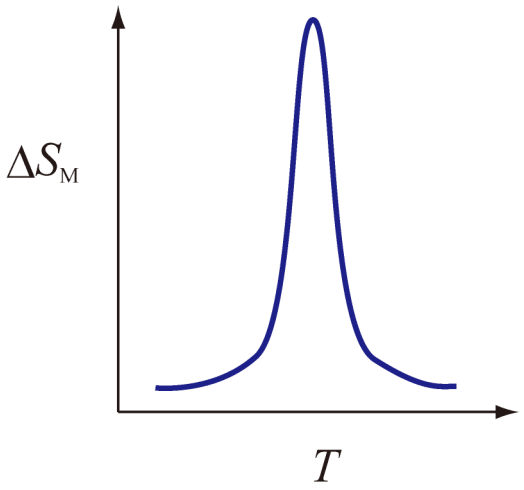
Our new approach

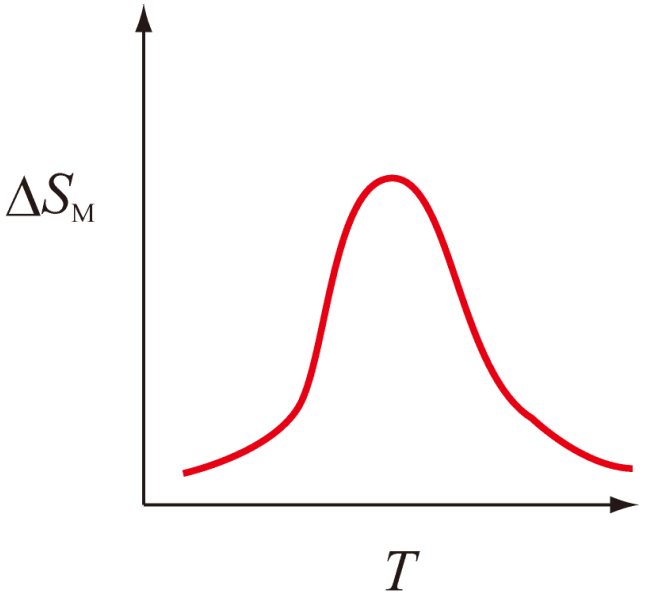
SOMT

(second-order magnetic transition)

FOMT

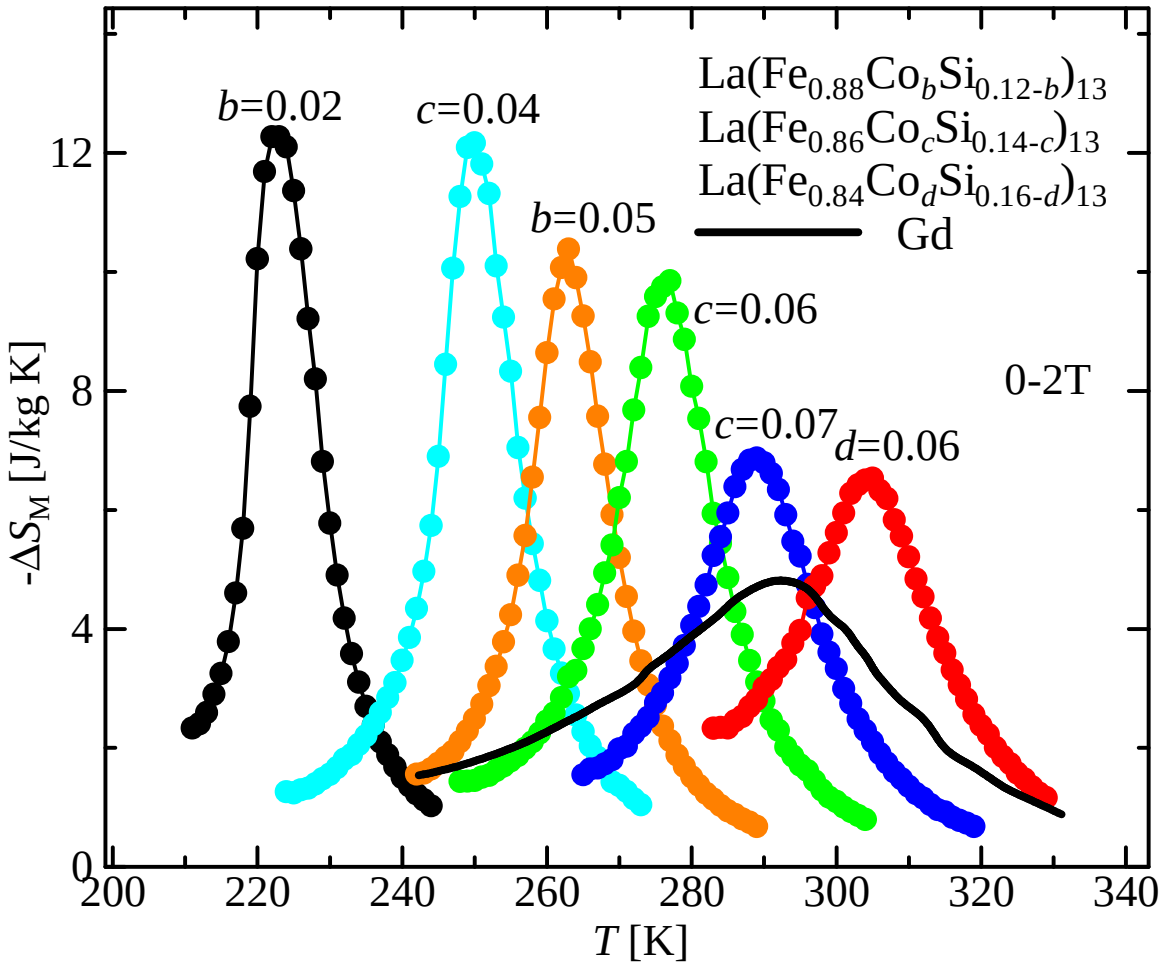




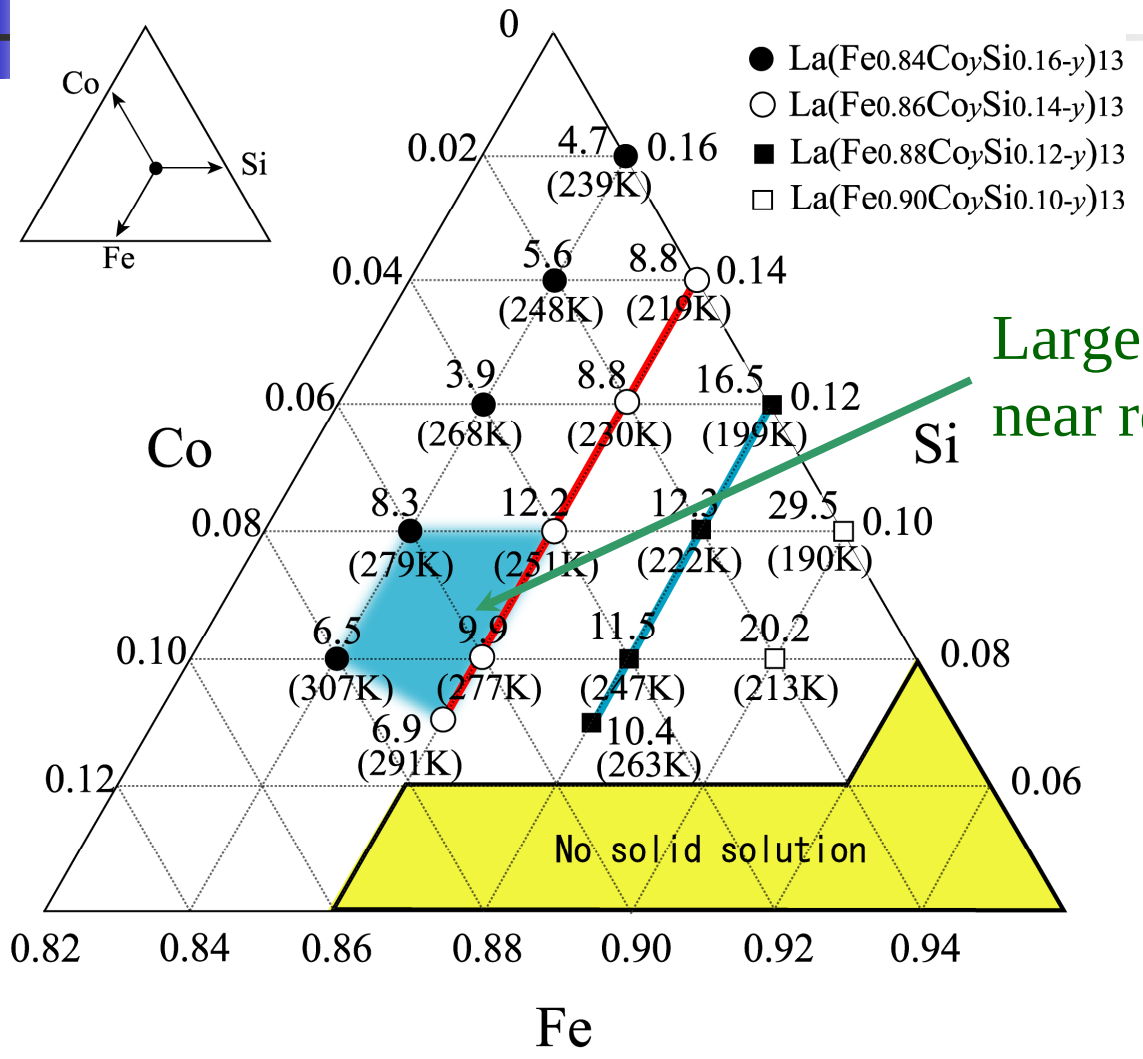


Broadening of a FOMT (continuous)

Example: $La(Fe_xCo_ySi_{1-x-y})_{13}$



Concentration dependence of ΔS_{Max} in 0-2T (J/K kg)



Large MCE is obtained near room temperature.

ΔS_{Max} (J/K kg)
(T_C)

Pressure: an effective tool to study the MCE

- Nature of magnetic transition

  broadening of a FOMT

- Enhancement of MCE

  MnAs?

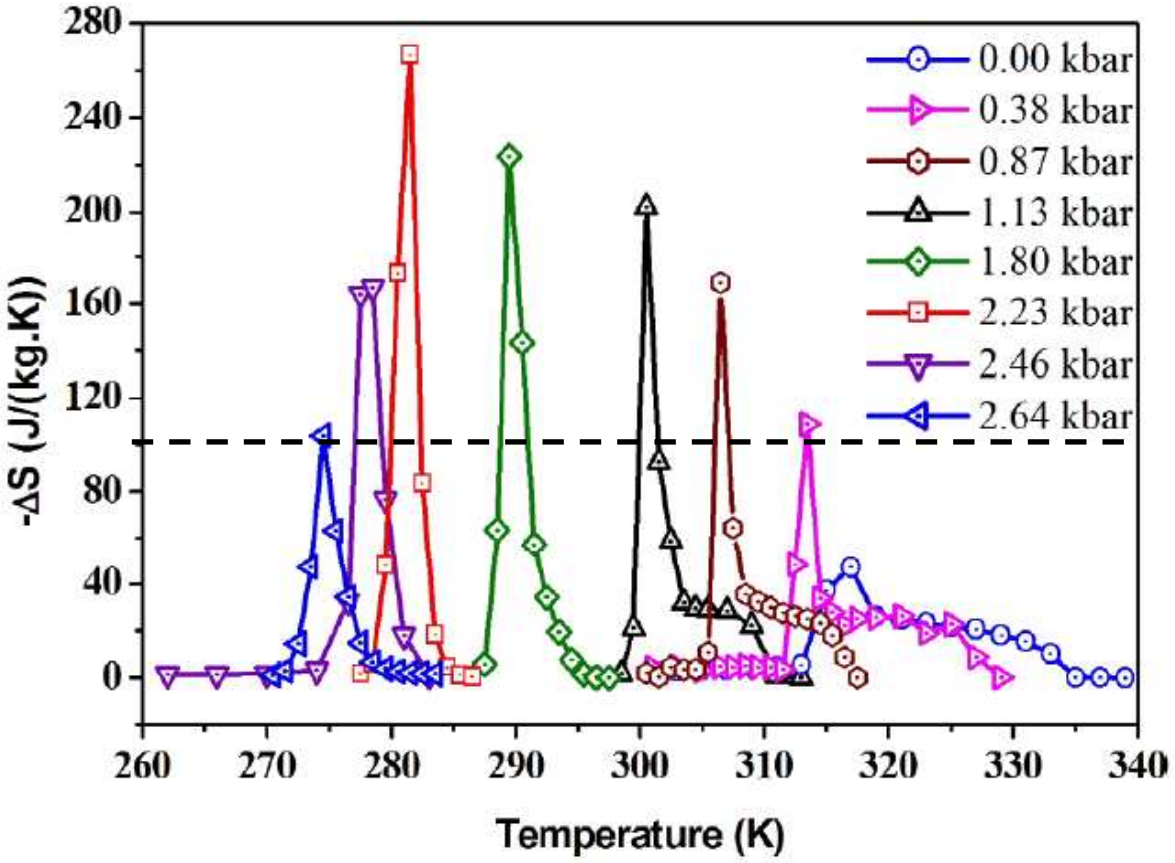
- Origin of MCE

  magnetic entropy change

  lattice entropy change

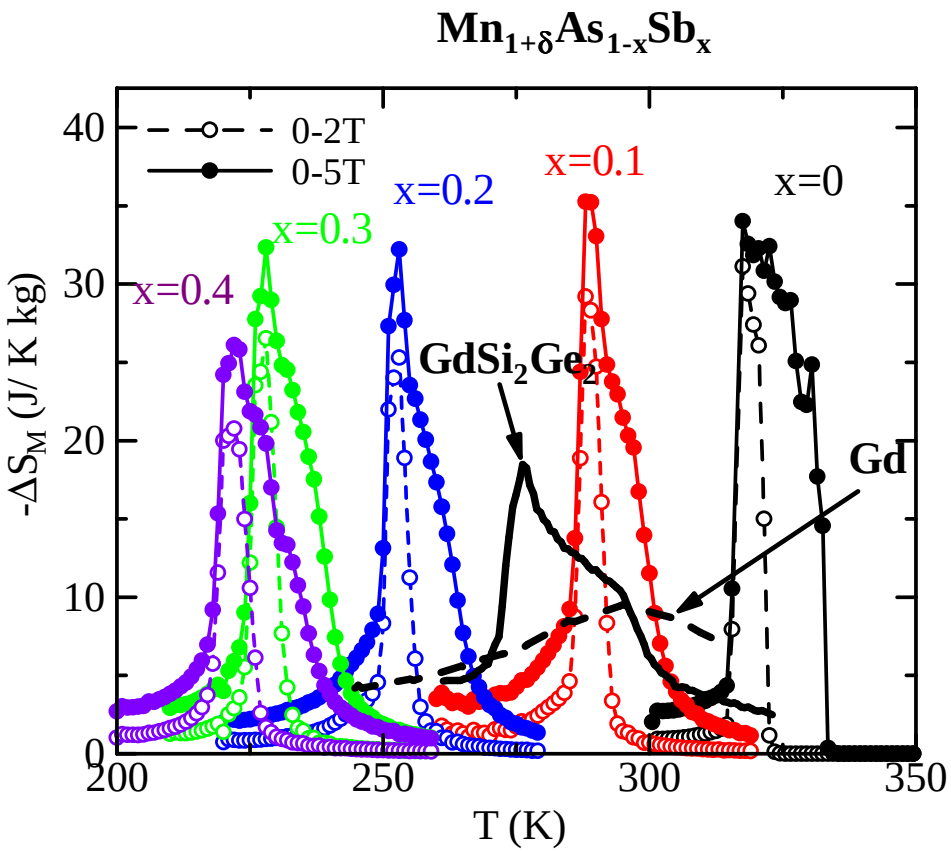
Colossal MCE of MnAs

Gama *et al*. 2004



$R\log(2S+1)$
$=103$J/kgK with $S=2$.

MCE of $MnAs_{1-x}Sb_x$ at ambient pressure



317K

T

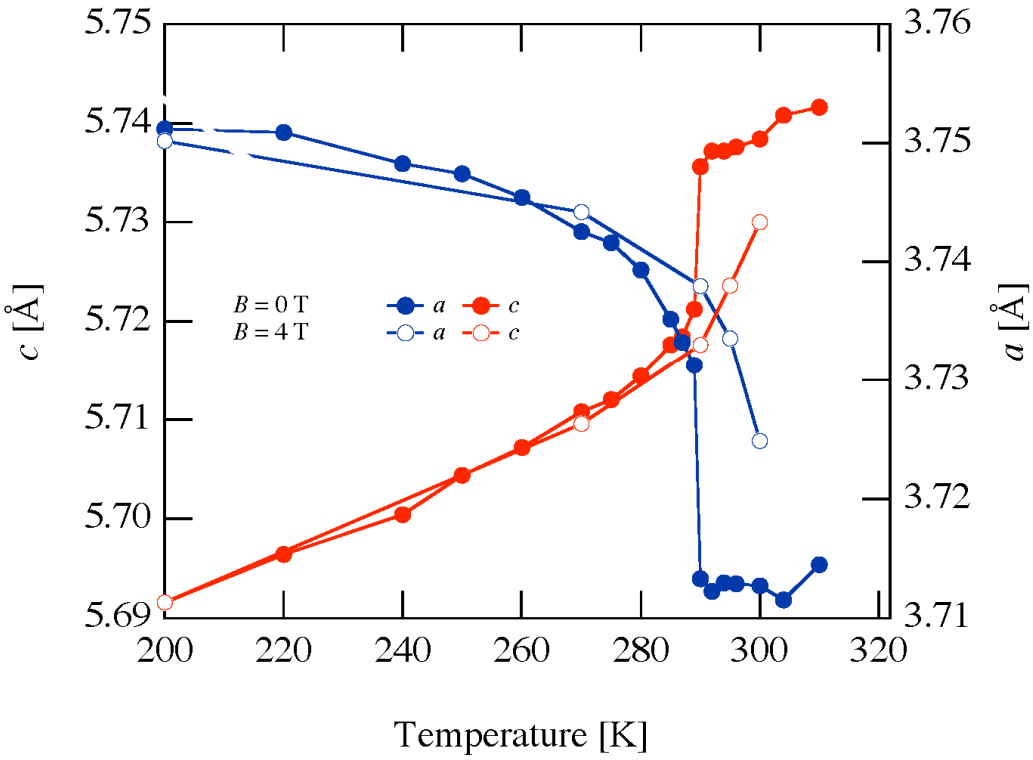
hexagonal NiAs-type ⟺ orthorhombic MnP-type

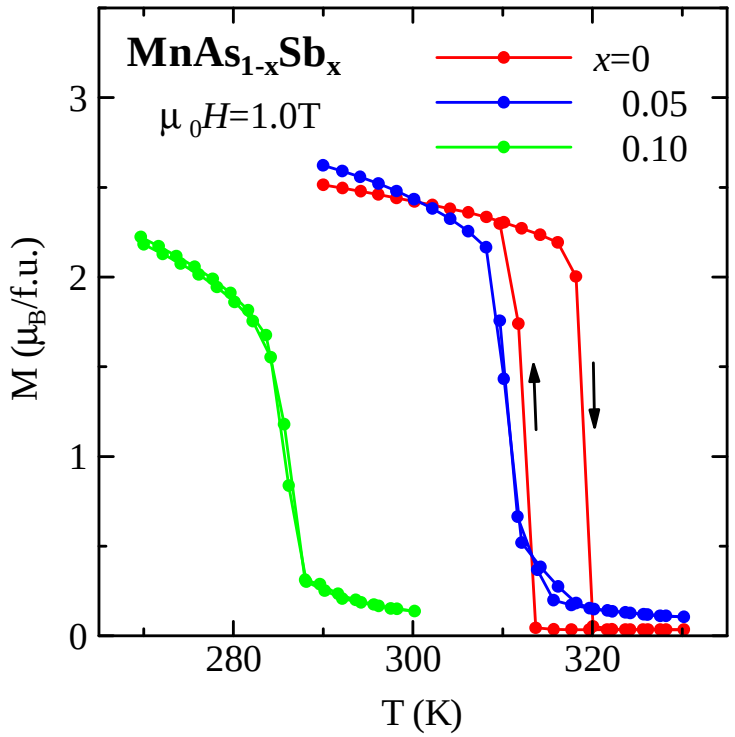
ferromagnetic — paramagnetic

FOMT accompanied by a structural transformation

FOMT of MnAs

No structural transformation in $MnAs_{1-x}Sb_x$





No structural transformation

Sb stabilizes the NiAs-type structure.

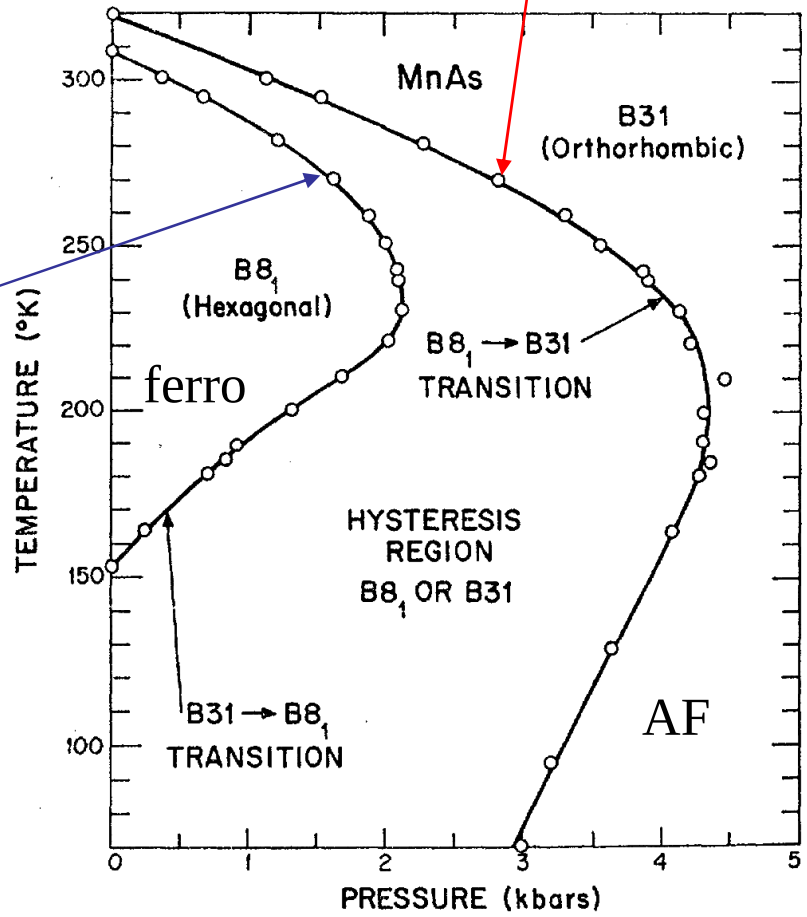
Thermal hysteresis is reduced

T - *p* phase diagram of MnAs

increasing *p*

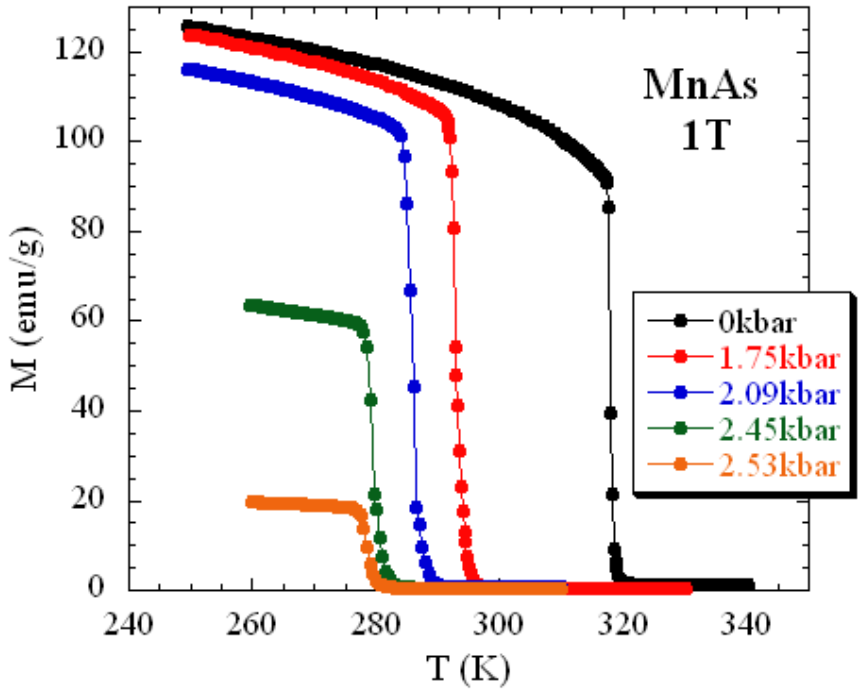
Pressure stabilizes the MnP-type structure.

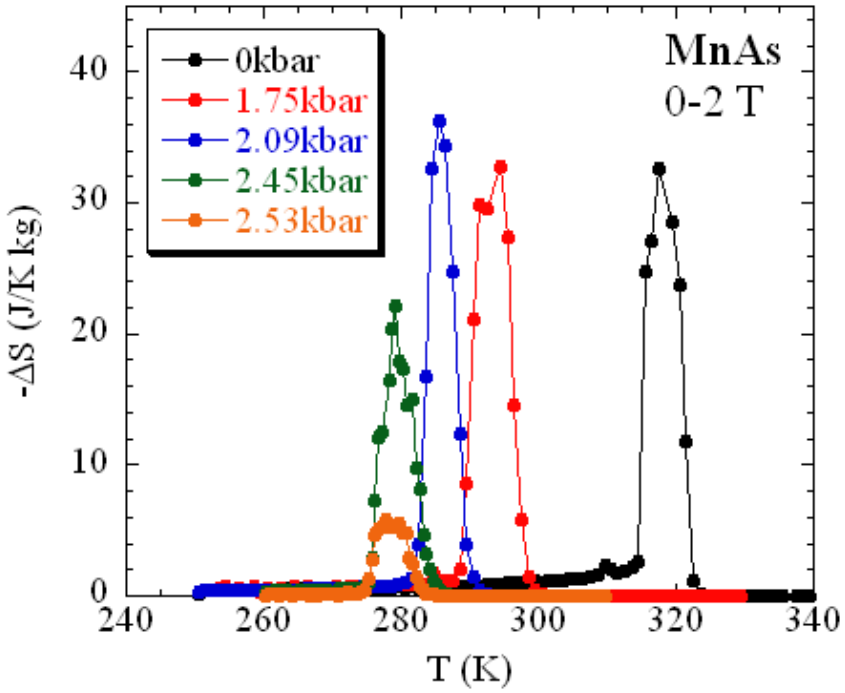
decreasing *p*



B8$_1$: NiAs-type
B31: MnP-type

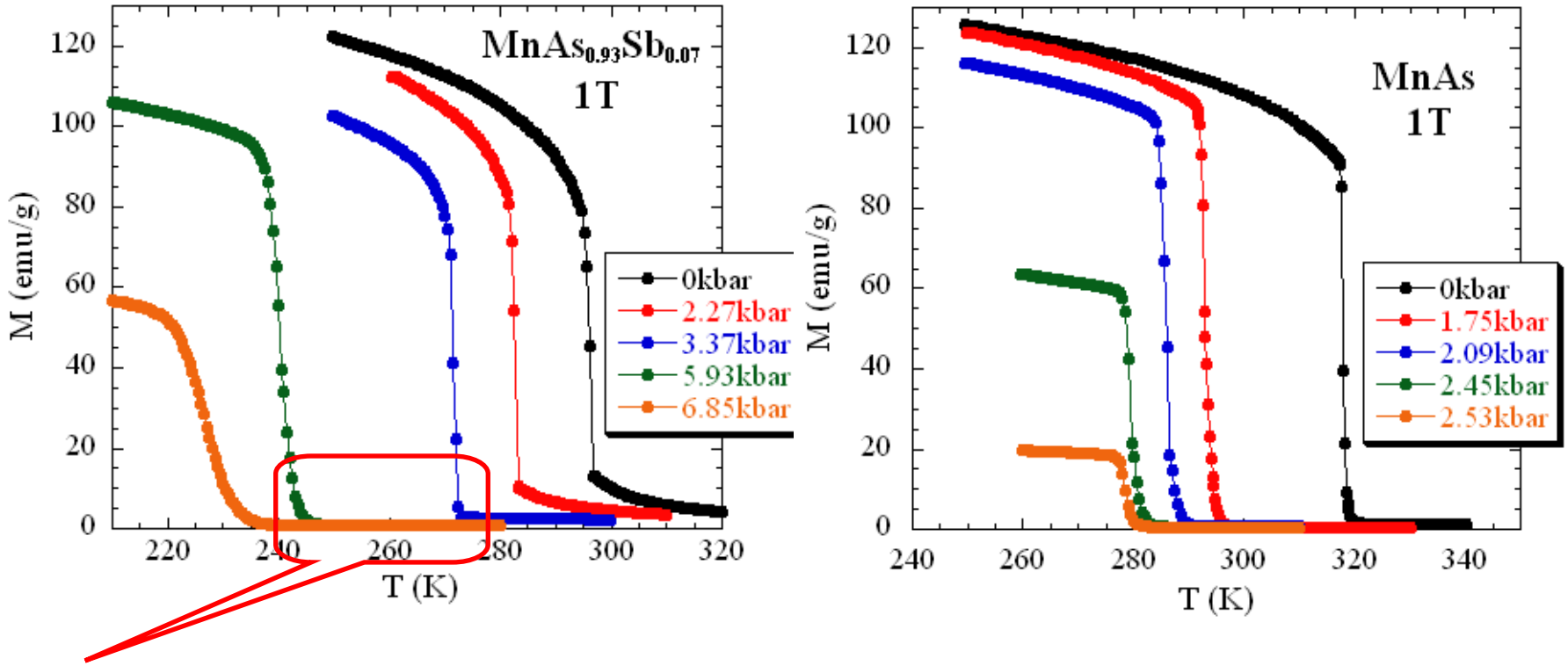
MCE of MnAs under pressure





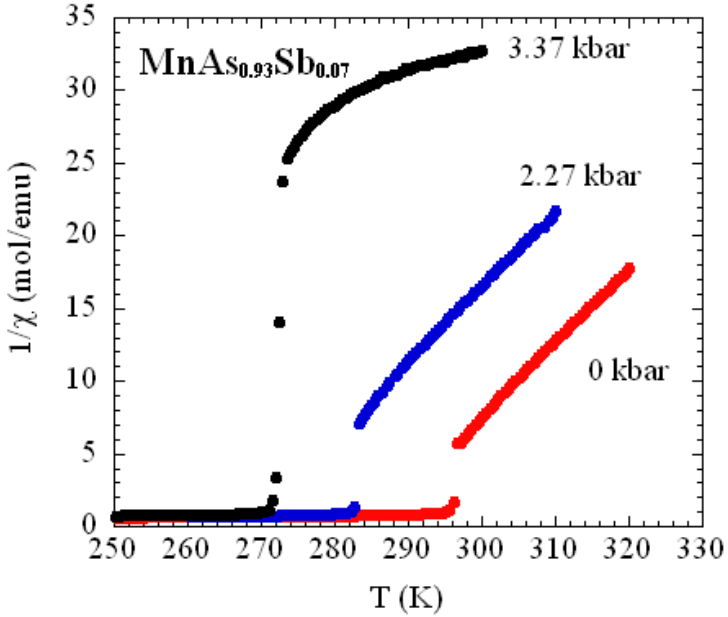
No strong enhancement of MCE by pressure was observed.

Magnetic transition of $MnAs_{0.93}Sb_{0.07}$ under pressure

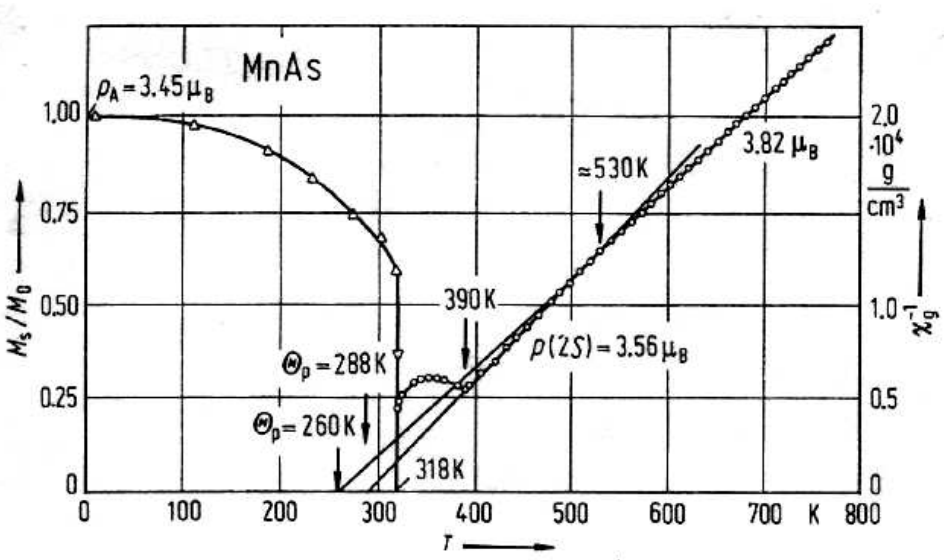


suggesting a structural transformation

χ^{-1}-T curve of $MnAs_{0.93}Sb_{0.07}$



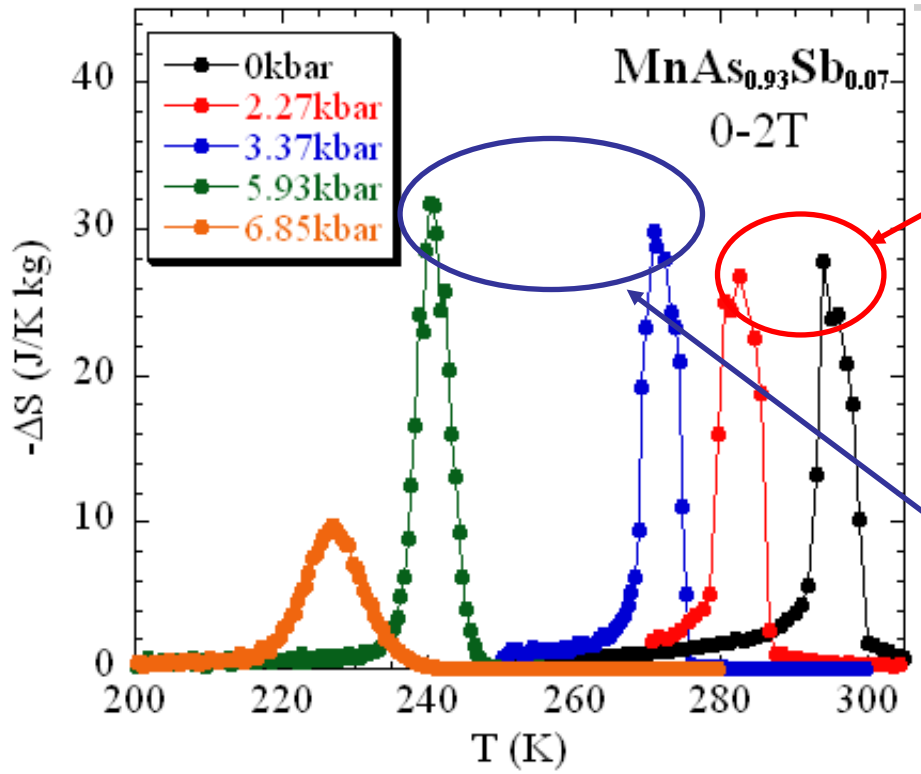
μ_{eff} = 4.0μ_B/Mn for 0 kbar



μ_{eff} = 4.45 μ_B/Mn for MnAs

$MnAs_{0.93}Sb_{0.07}$ undergoes the first-order NiAs-type → MnP-type transition above 3.37 kbar.

MCE of $MnAs_{0.93}Sb_{0.07}$ under pressure



NiAs→NiAs

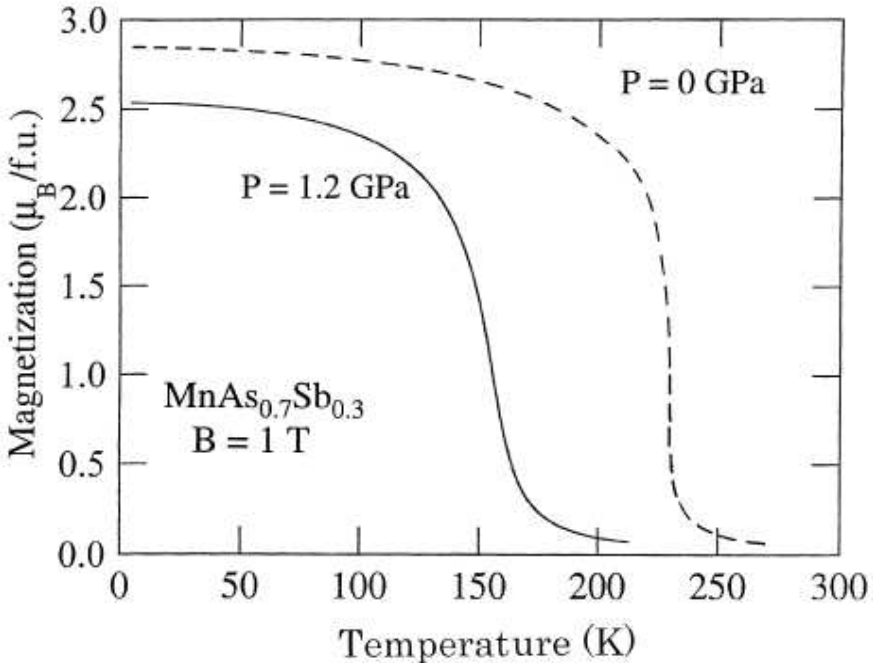
$$\Delta S = \Delta S_{\mathrm{M}} + \Delta S_{\mathrm{st}}$$

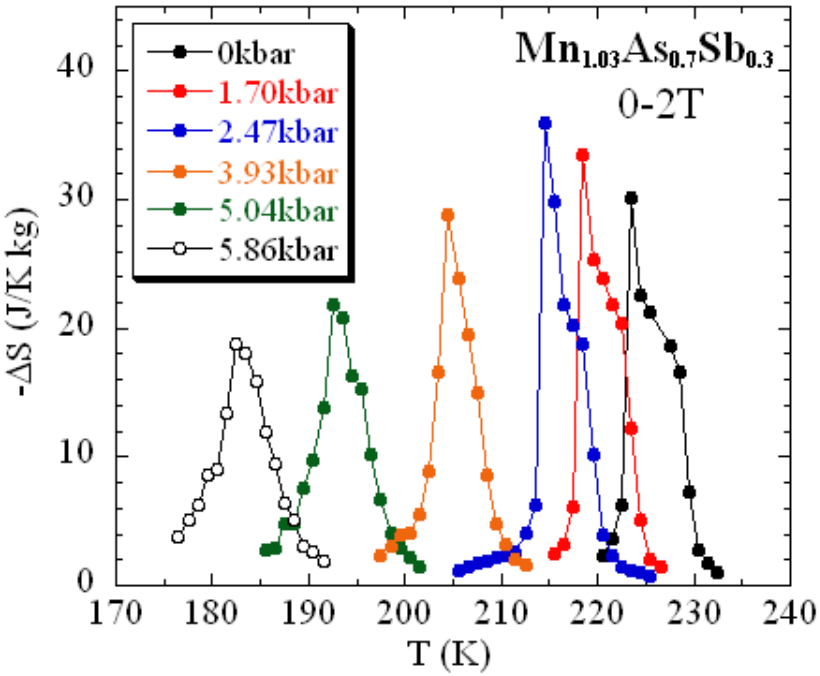
NiAs→MnP

- Lattice entropy change due to a structural transformation, ΔS_{st} is small in the $MnAs_{1-x}Sb_x$ system.

MCE of $MnAs_{0.7}Sb_{0.3}$ under pressure

Goto *et al*., 2001





The NiAs-type structure is stable up to 12 kbar.

Magnetic phase diagram of $La(Fe_xSi_{1-x})_{13}$

Compounds are formed in $0.81 \leq x \leq 0.90$.

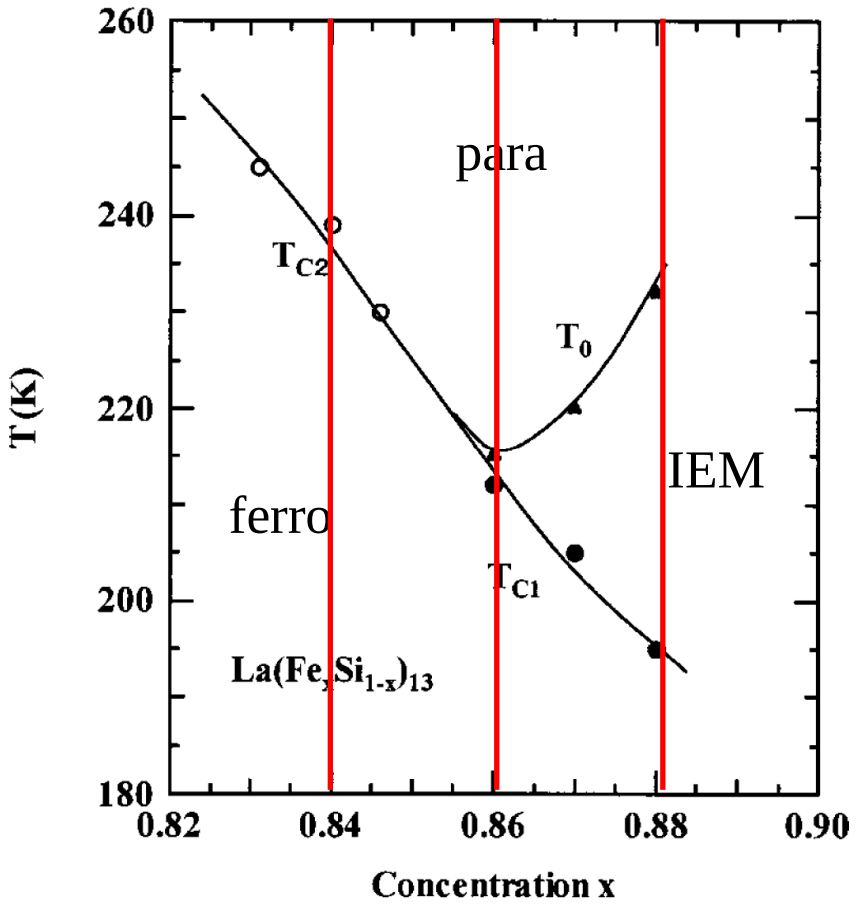
The FOMT appears in $x > 0.86$.

We studied MCE under pressure for

x=0.84 (SOMT)

0.86 (critical)

0.88 (FOMT)



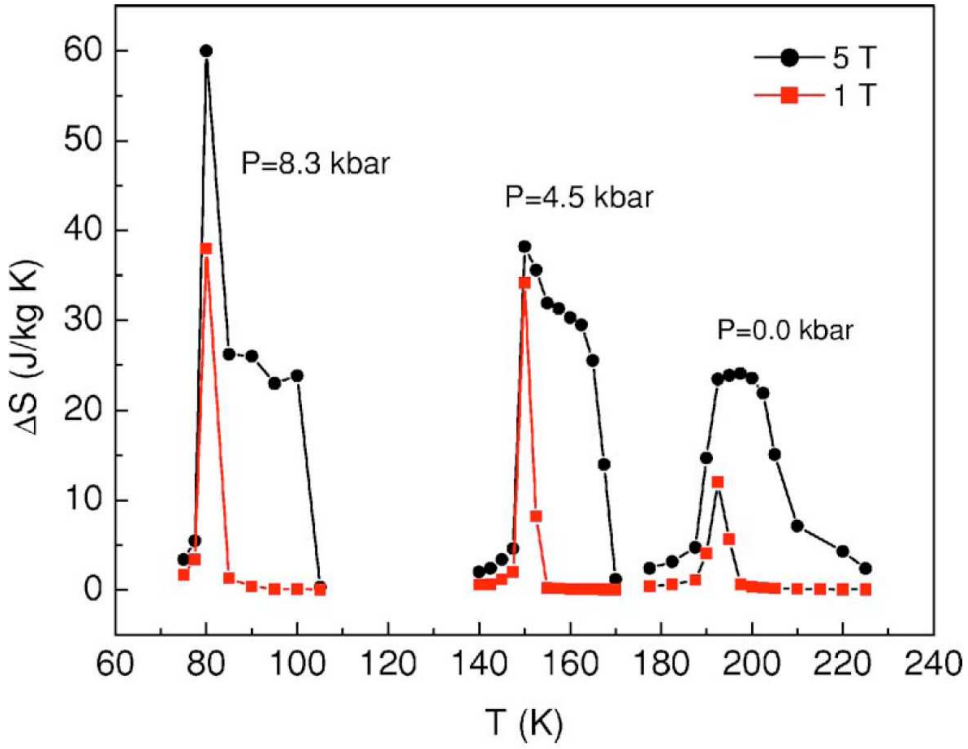
Fujita *et al.*, 2001

Previous reports

Previous measurements are concentrated on the FOMT.

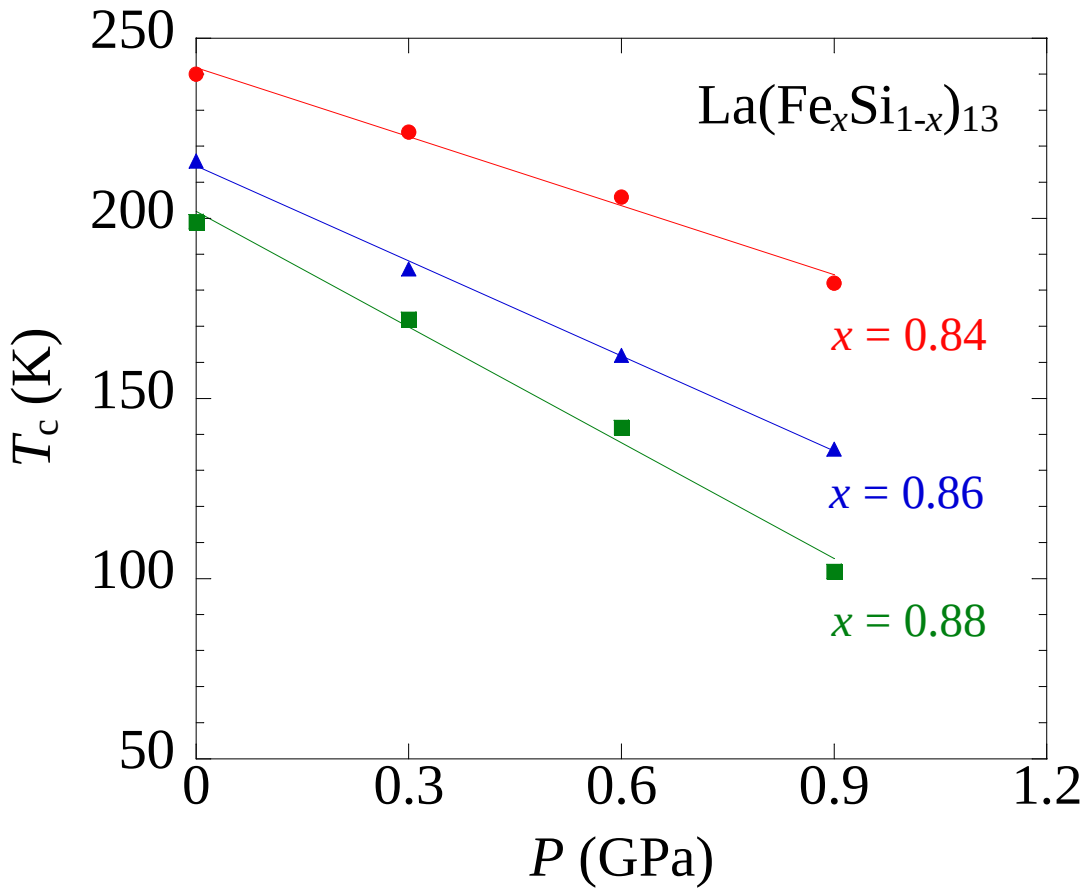
$LaFe_{11.6}Si_{1.4}$ (x=0.892)
(Sun *et al*., 2006)

$LaFe_{11.5}Si_{1.5}$ (x=0.885)
(Jia *et al*., 2007).



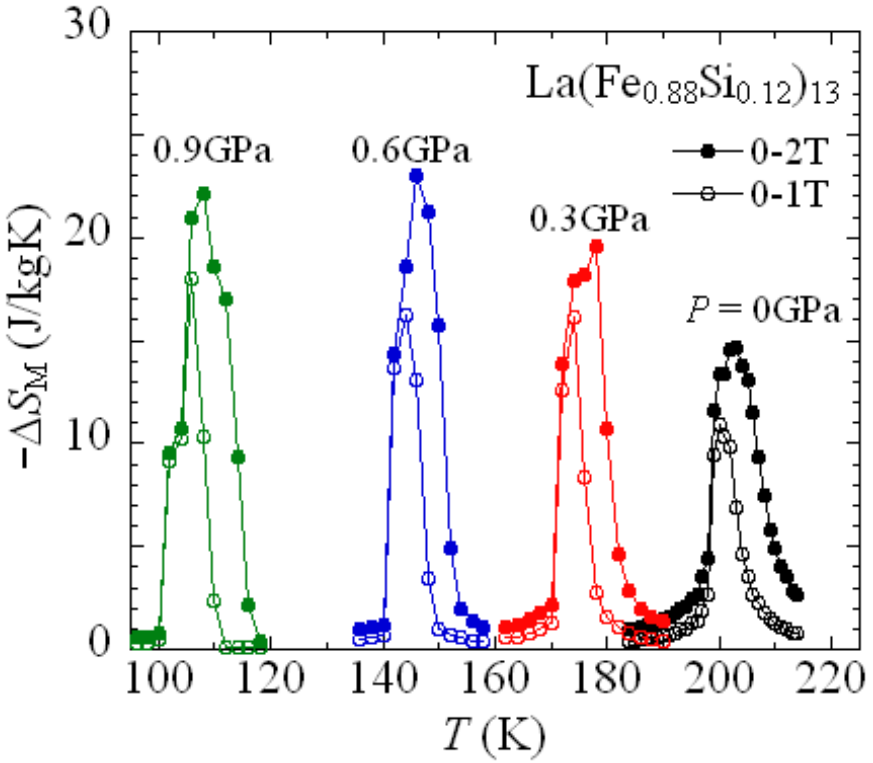
Sun *et al*., 2006

Pressure dependence of T_C

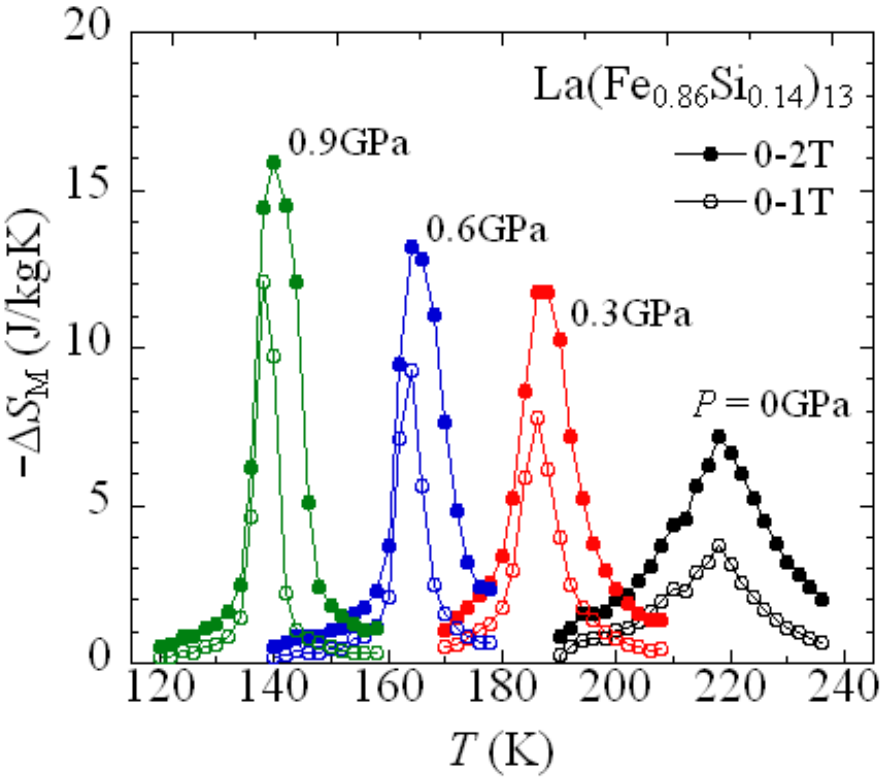


The results are in agreement with the previous reports by Fuita *et al*. (2001).

Pressure dependence of MCE for x=0.88 and 0.86

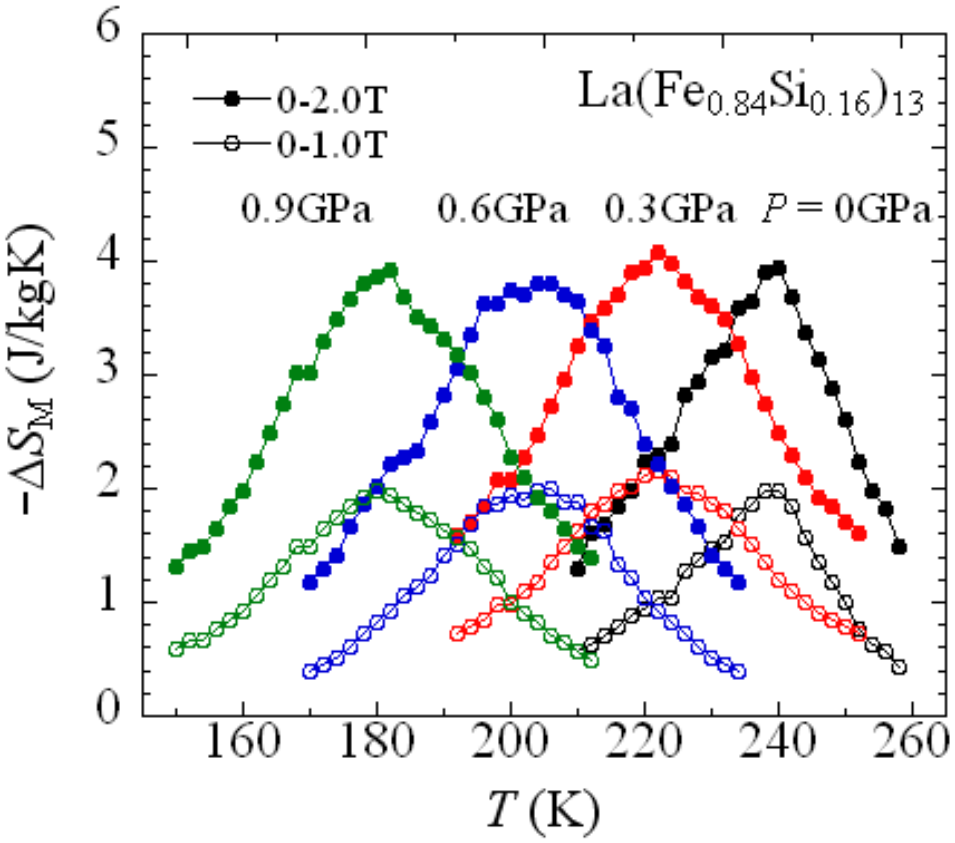


FOMT



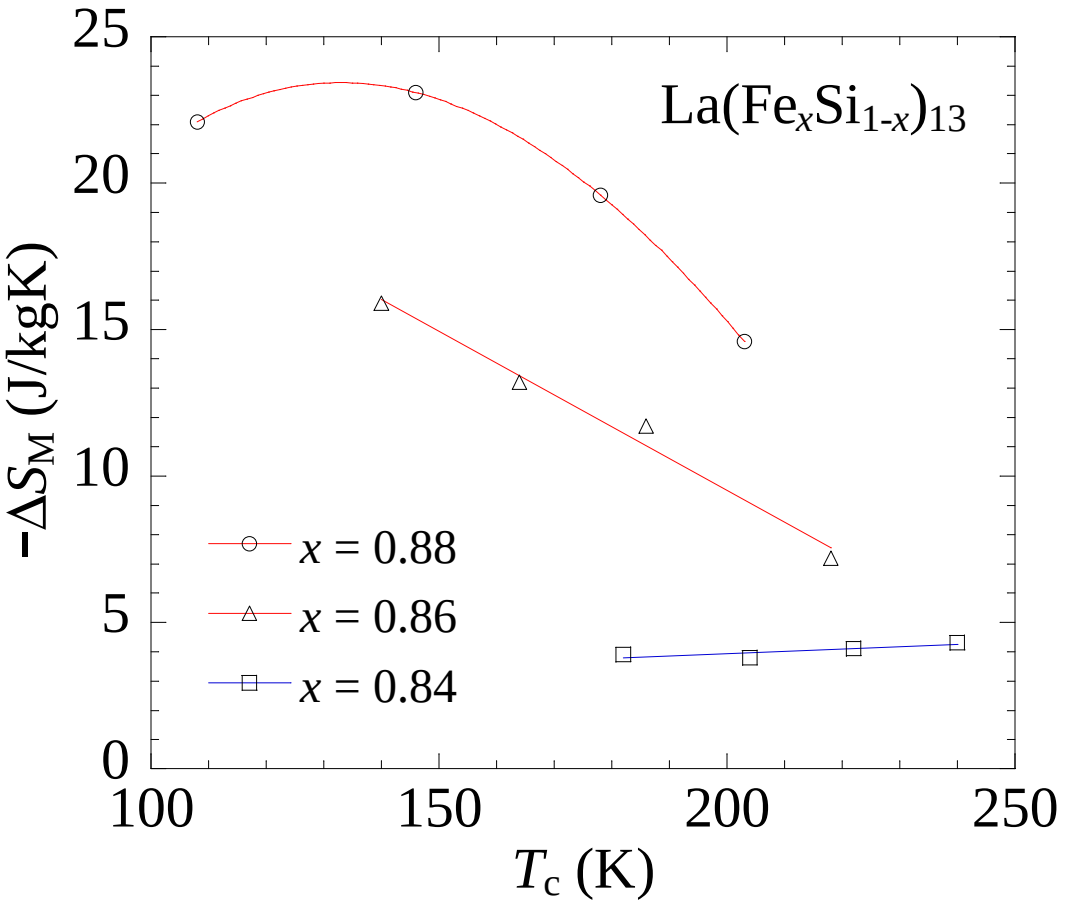
SOMT → FOMT

Pressure dependence of MCE for x=0.84



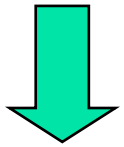
The SOMT persists up to 0.9 GPa.

Summary of ΔS of $La(Fe_xSi_{1-x})_{13}$ under pressure



Conclusions : $MnAs_{1-x}Sb_x$

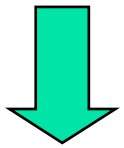
- No strong enhancement of the MCE was observed.
- Pressure stabilizes the MnP-type structure.
- $MnAs_{0.93}Sb_{0.07}$ undergoes the first-order NiAs-type $\rightarrow$ MnP-type transition above 3.37 kbar.
- The lattice entropy change due to a structural transformation is small.



Broadening of the FOMT seems difficult.

Conclusions : $La(Fe_xSi_{1-x})_{13}$

- The pressure effect on the MCE strongly depends on x.
- A FOMT is induced by pressure for $x = 0.86$, which enhances the peak value of ΔS.



Broadening of the FOMT seems possible.