Magnetization and magneto-acoustics of $HoFe_5Al_7$ single crystal in high magnetic fields

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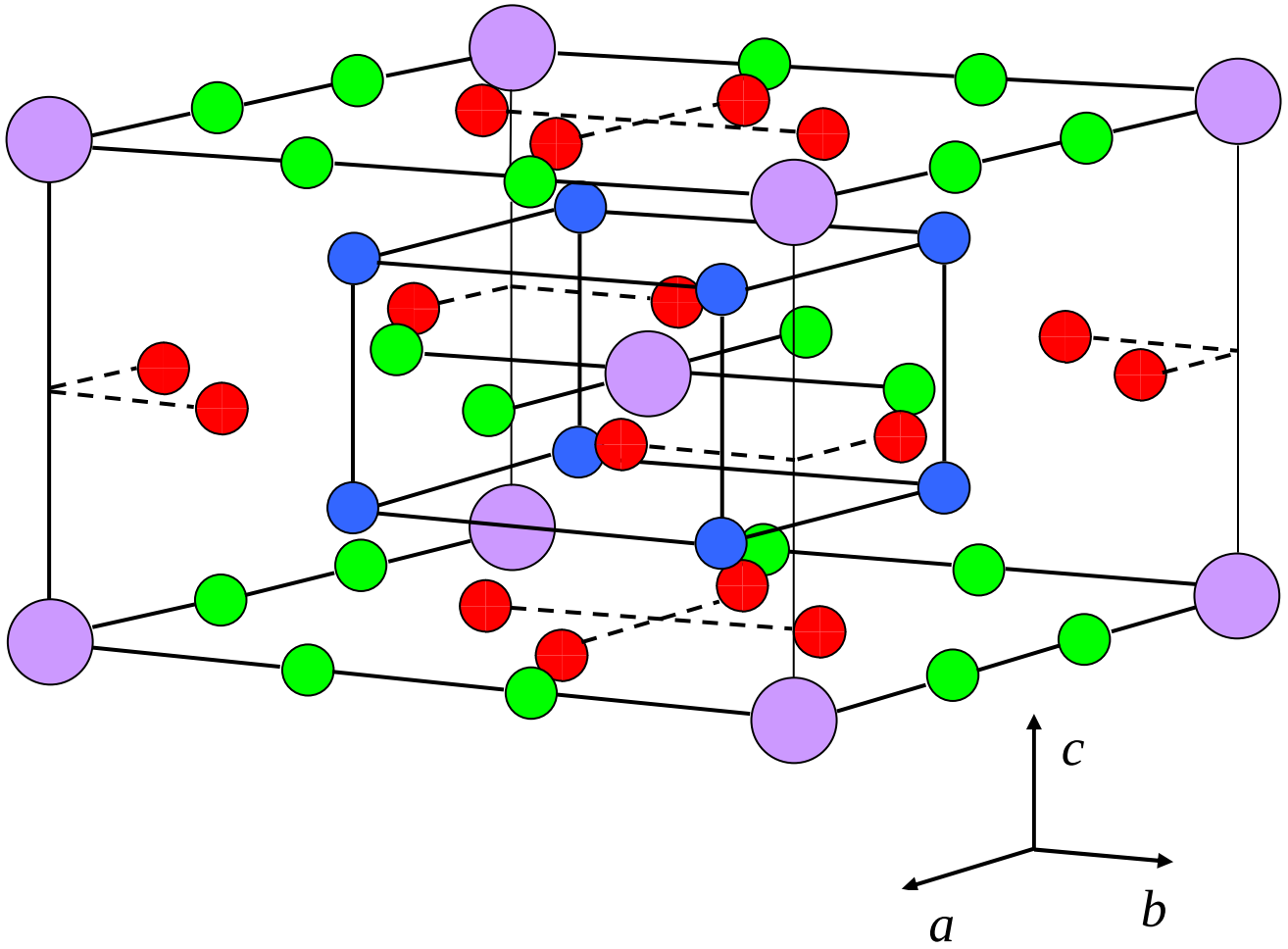
$ThMn_{12}$ crystal lattice



RFe_5Al_7
Tetragonal lattice
I4/mmm
***Z* = 2**

R	2a	
Fe1	8f	
Fe2	8j	
Al1	8i	
Al2	8j	

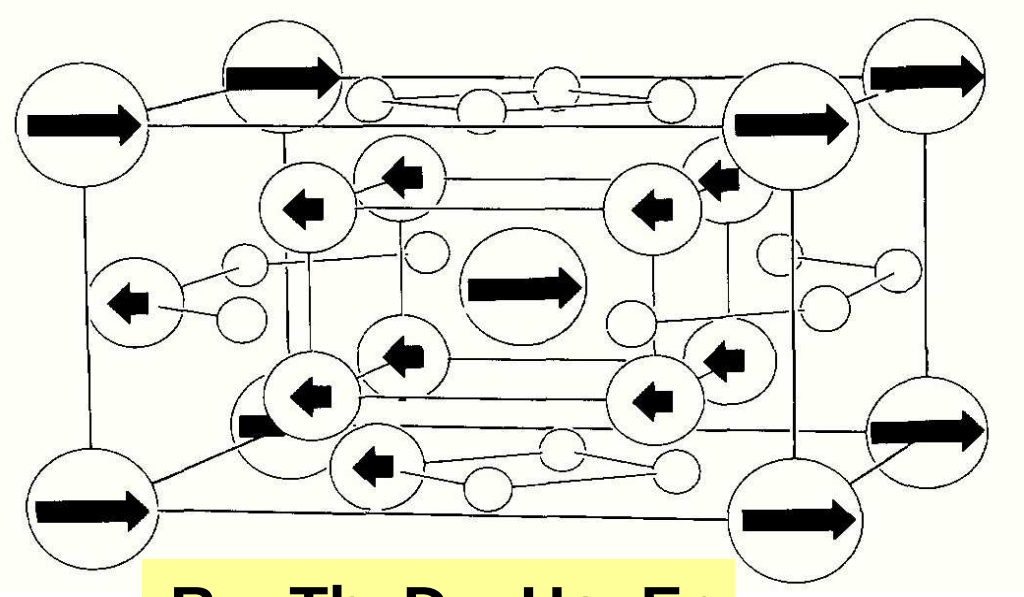
***a* ≈ 8.7 Å**
***c* ≈ 5.1 Å**
***c/a* ≈ 0.59**

RFe_5Al_7 compounds

R	Magnetic order
U	Ferromagnetic
Gd Tb Dy Ho Er Tm	Ferrimagnetic
Sm Y Yb Lu	???

207 K ≤ T_o ≤ 268 K

$YbFe_5Al_7$ $GdFe_5Al_7$



R = Tb, Dy, Ho, Er

I. Felner, J. Less-Common Met. 72 (1980) 241.

I. Felner *et al*., J. Magn. Magn. Mater. 38 (1983) 172.

W. Kockelmann *et al.*, J. Alloys Comp. 207-208 (1994) 311.

A.V. Andreev *et al*., J. Alloys Comp. 492 (2010) 52.

“Negative magnetization” of RFe_5Al_7 compounds

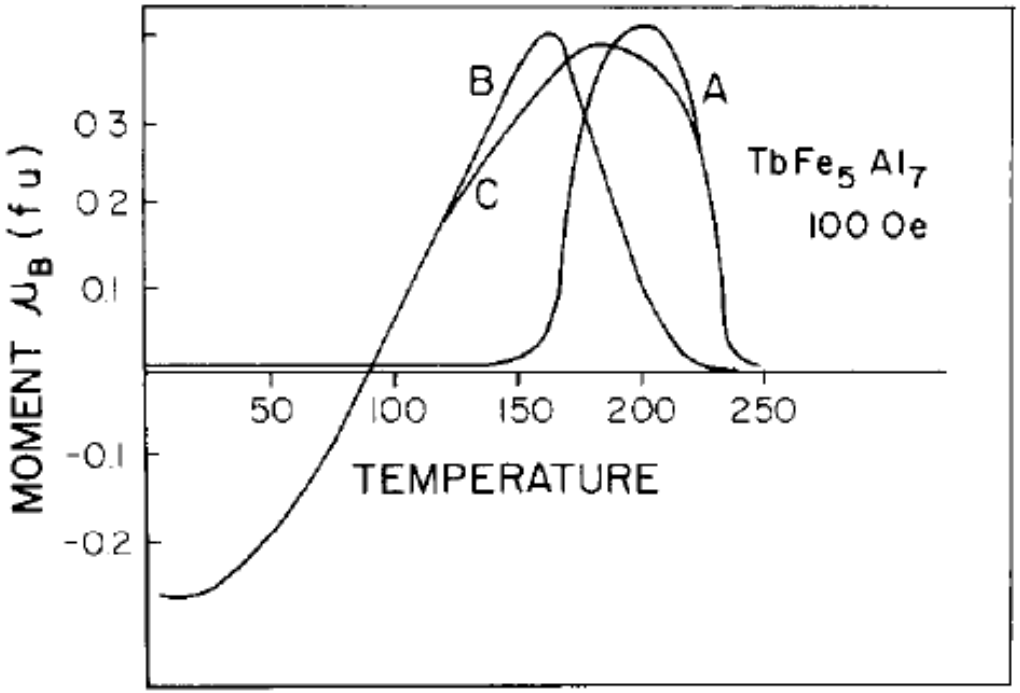


Fig. 7. Temperature dependence of $TbFe_5Al_7$ magnetization, sample cooled to 4.1 K in zero field (A), cooled to 4.1 K in 100 Oe, temperature increase (B), and temperature decrease (C) in 100 Oe.

I. Felner *et al*., Solid State Comm. 44 (1982) 691.

Magnetic anisotropy of RFe_5Al_7

Neutron diffraction	
Orientation of magnetic moments	
$\perp$ *c* axis	$\parallel$ *c* axis
R = Tb, Dy, Ho, Er	R = Tm

W. Kockelmann *et al.*, J. Alloys Comp. 207-208 (1994) 311.

Magnetization studies

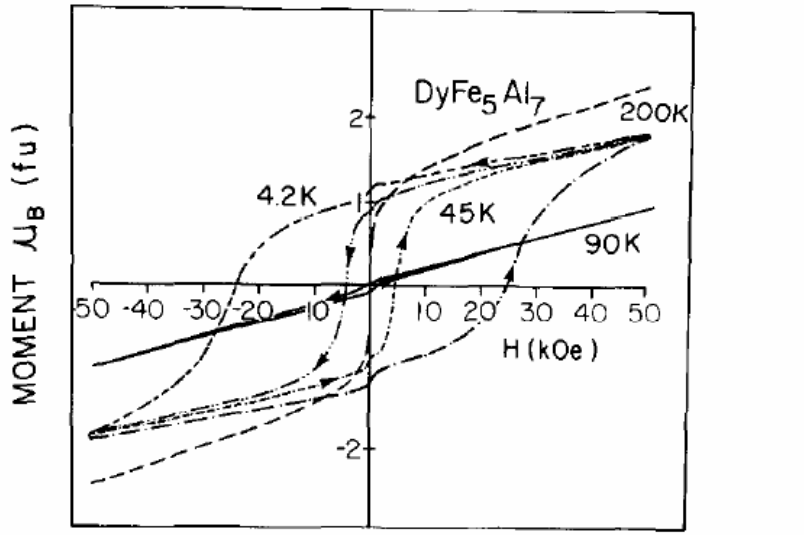


Fig. 10. Hysteresis curves of $DyFe_5Al_7$ at different temperatures.

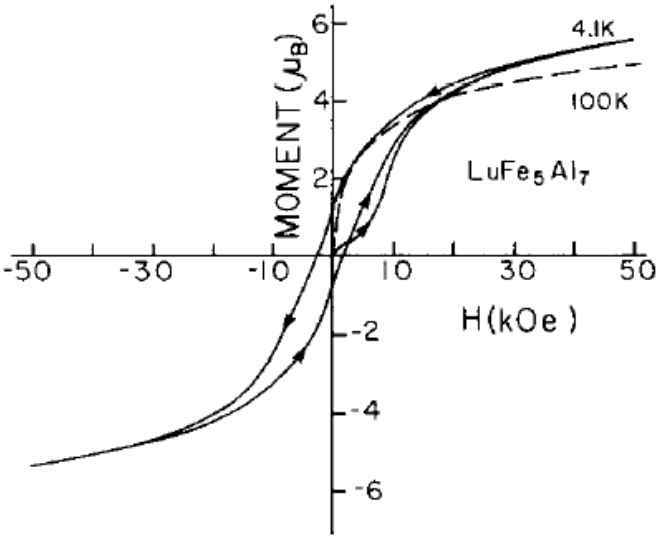


Fig. 16. Hysteresis curves of $LuFe_5Al_7$. Almost identical curves were obtained for YFe_5Al_7 and $YbFe_5Al_7$.

I. Felner *et al.*, J. Magn. Magn. Mater. 38 (1983) 172.

Experiment

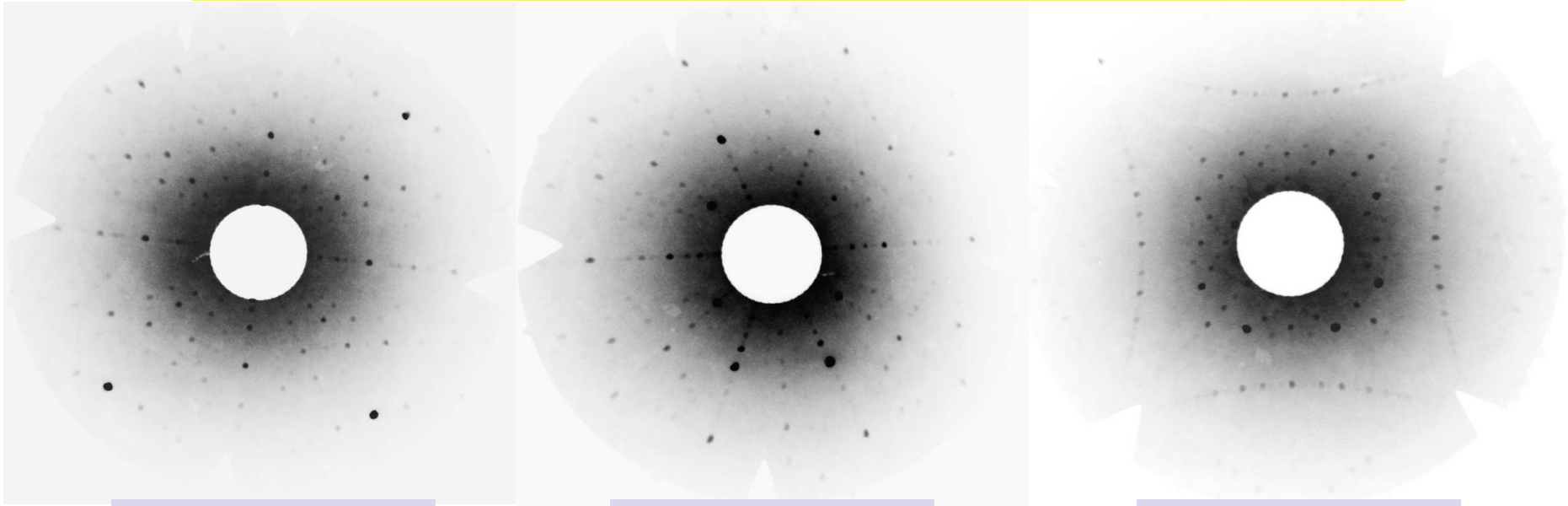
1. Synthesis of $HoFe_5Al_7$ single crystal by modified Czochralski method in tri-arc furnace;
2. X-ray powder diffraction analysis;
3. Shaping and orientation of single crystal along the [100], [110] and [001] directions;
4. Magnetic and acoustic study of single crystal in static magnetic fields:
- Magnetization isotherms along principal axes in magnetic fields up to 14 T (PPMS-14, Quantum Design);
- Acoustic properties in magnetic fields up to 18 T (pulse-echo technique);
5. Magnetic and acoustic study of single crystal in pulsed magnetic fields up to 60 T.

Characterization of $HoFe_5Al_7$ single crystal

X-ray powder diffraction

a = 8.678 Å, *c* = 5.038 Å

Laue diffraction patterns



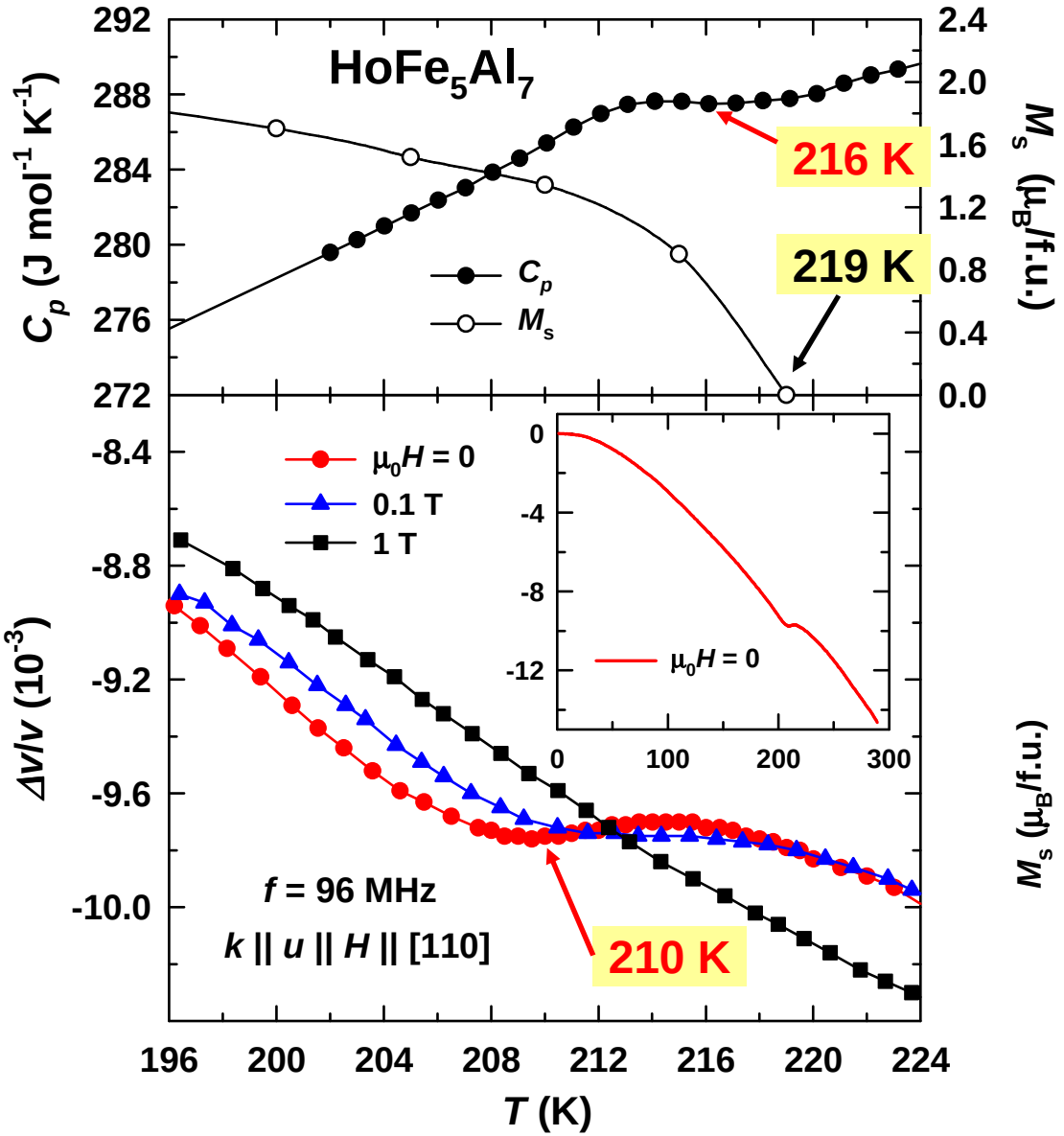
|| [100] axis

|| [110] axis

|| [001] axis

High quality of $HoFe_5Al_7$ single crystal

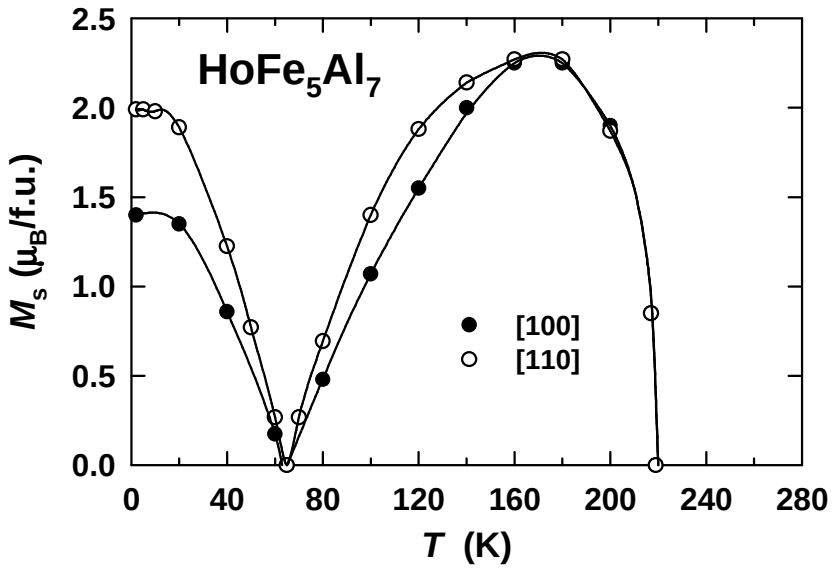
Magnetic ordering temperature



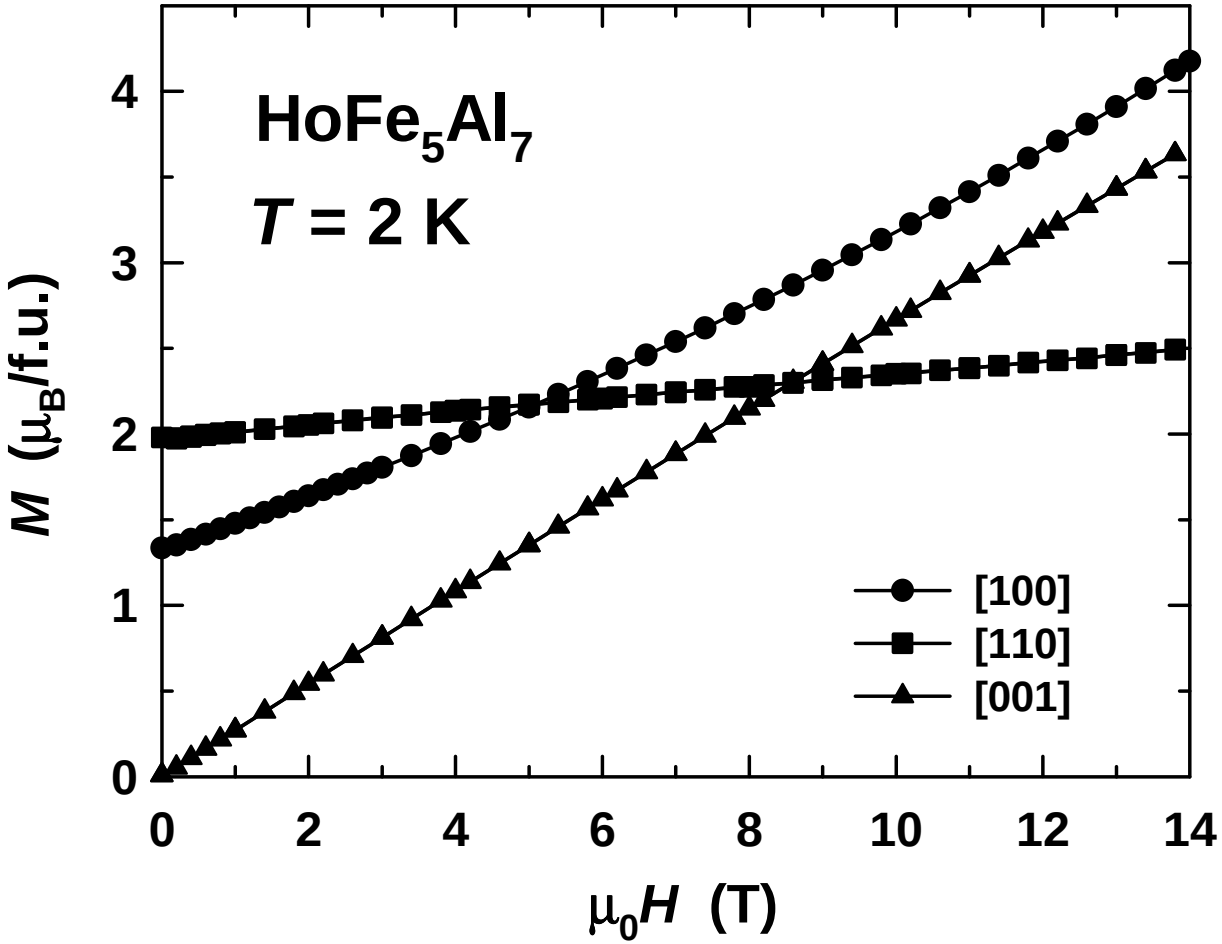
$HoFe_5Al_7$
Ferrimagnet

T_C = 213 K

T_{comp} = 65 K



Magnetization curves of $HoFe_5Al_7$ single crystal at T = 2 K



Spontaneous magnetic moment

M_s = 2.0 μ_B/f.u.

$$\frac{M_s^{100}}{M_s^{110}} = \cos 45^o$$

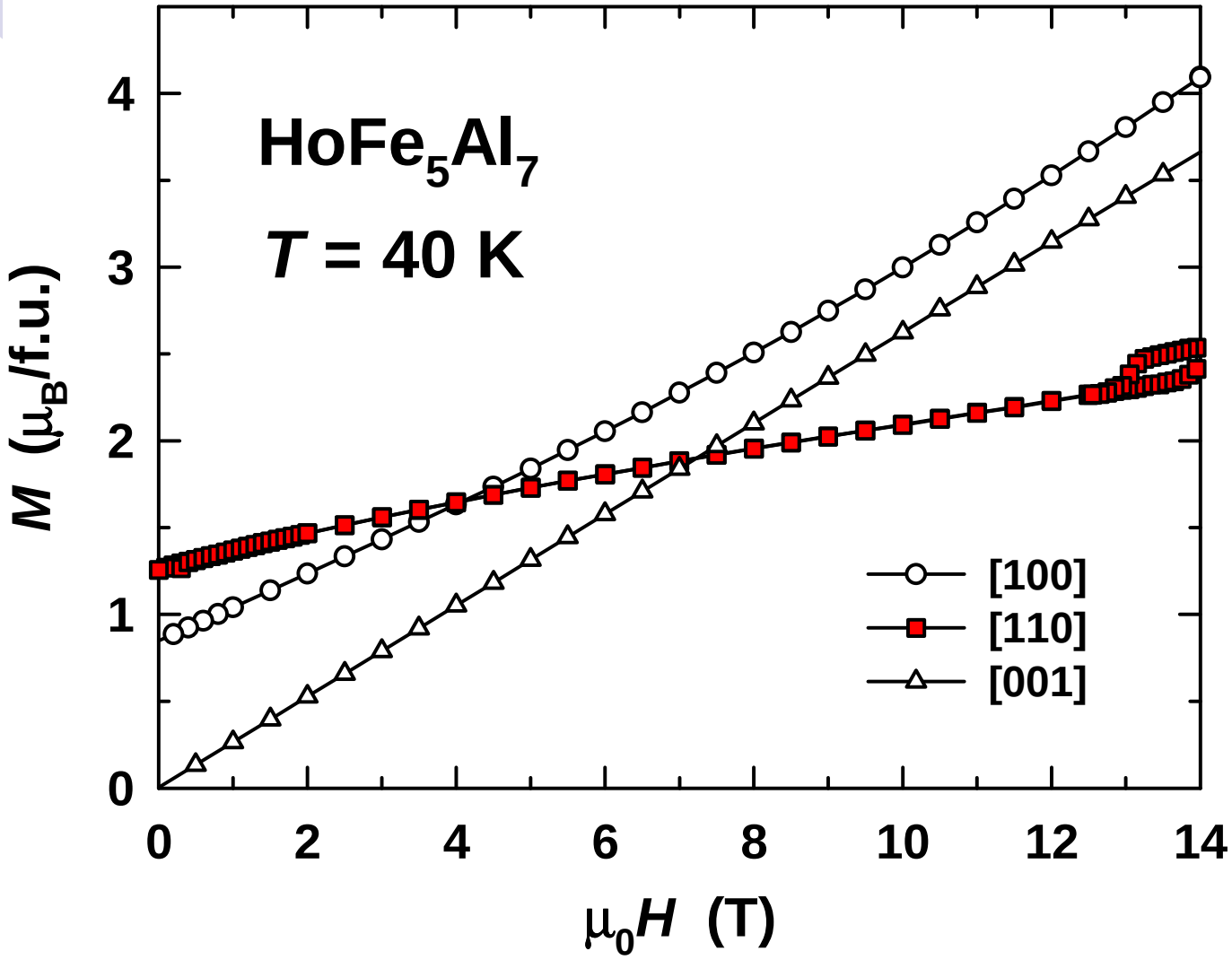
$M(Ho^{3+})$ = 10 μ_B/f.u.

M(Fe) = $M(Ho^{3+})$- M_s = 8 μ_B/f.u.

1.6 μ_B/Fe atom

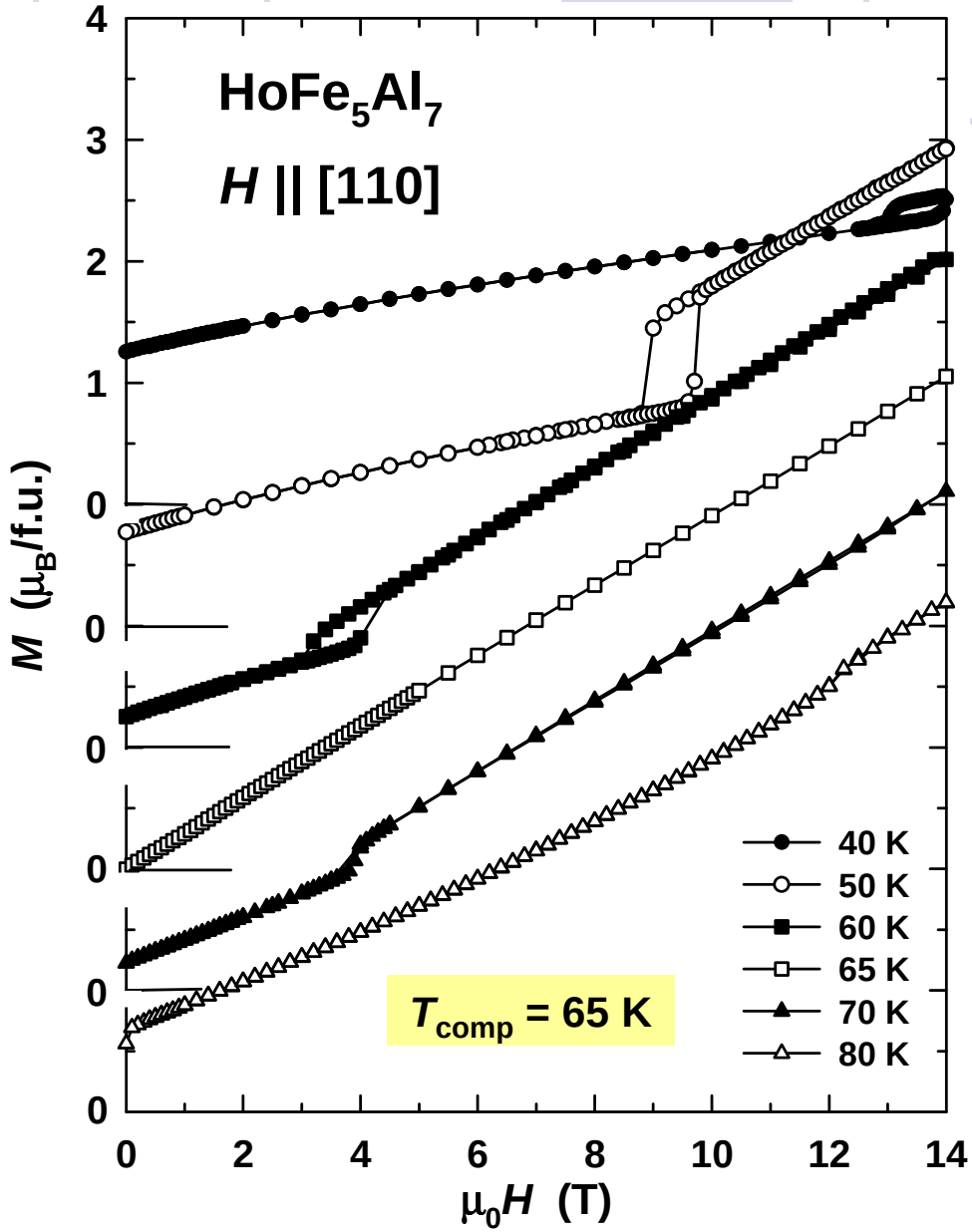
- **Easy-plane anisotropy** with EMD along [110];
- Large **in-plane anisotropy** between [100] and [110] axes;
- Strong paraprocess with crossing.

Field-induced magnetic transition

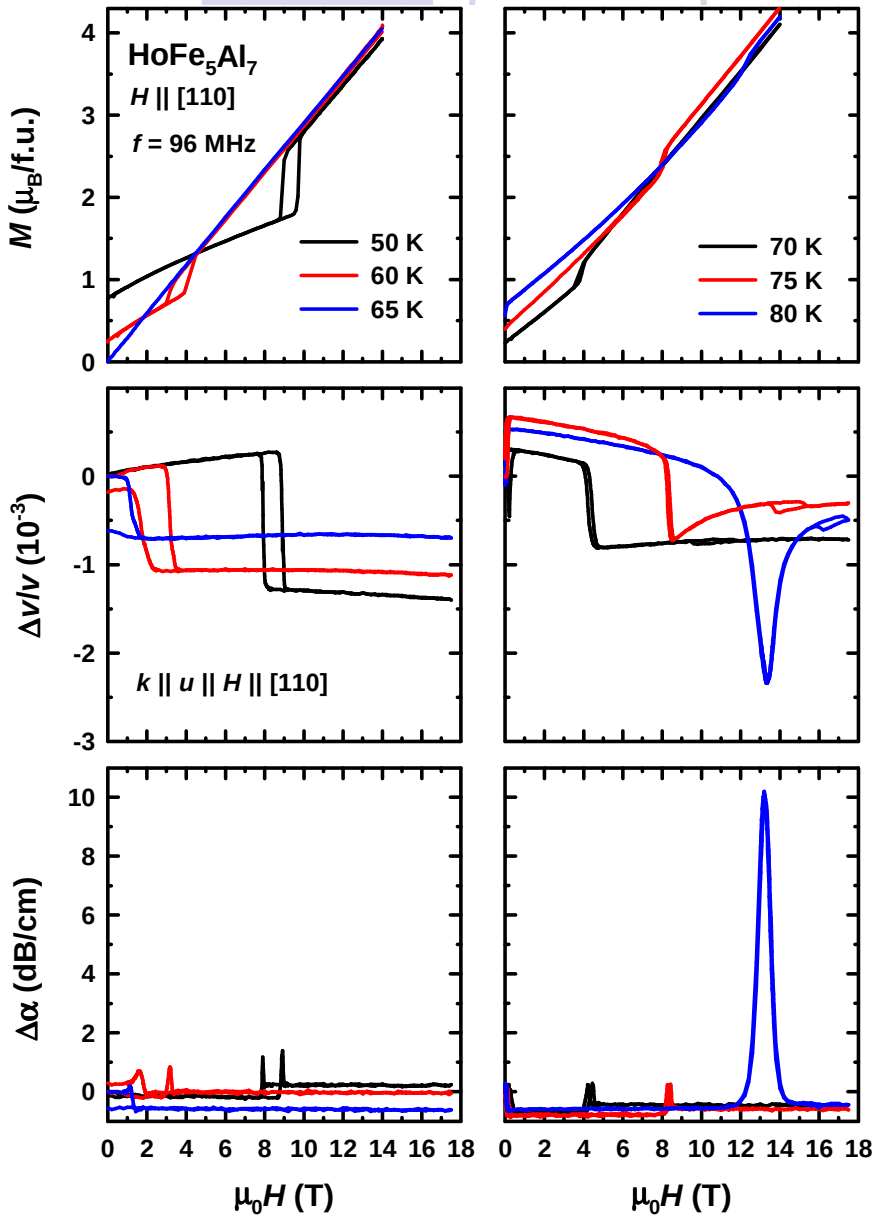


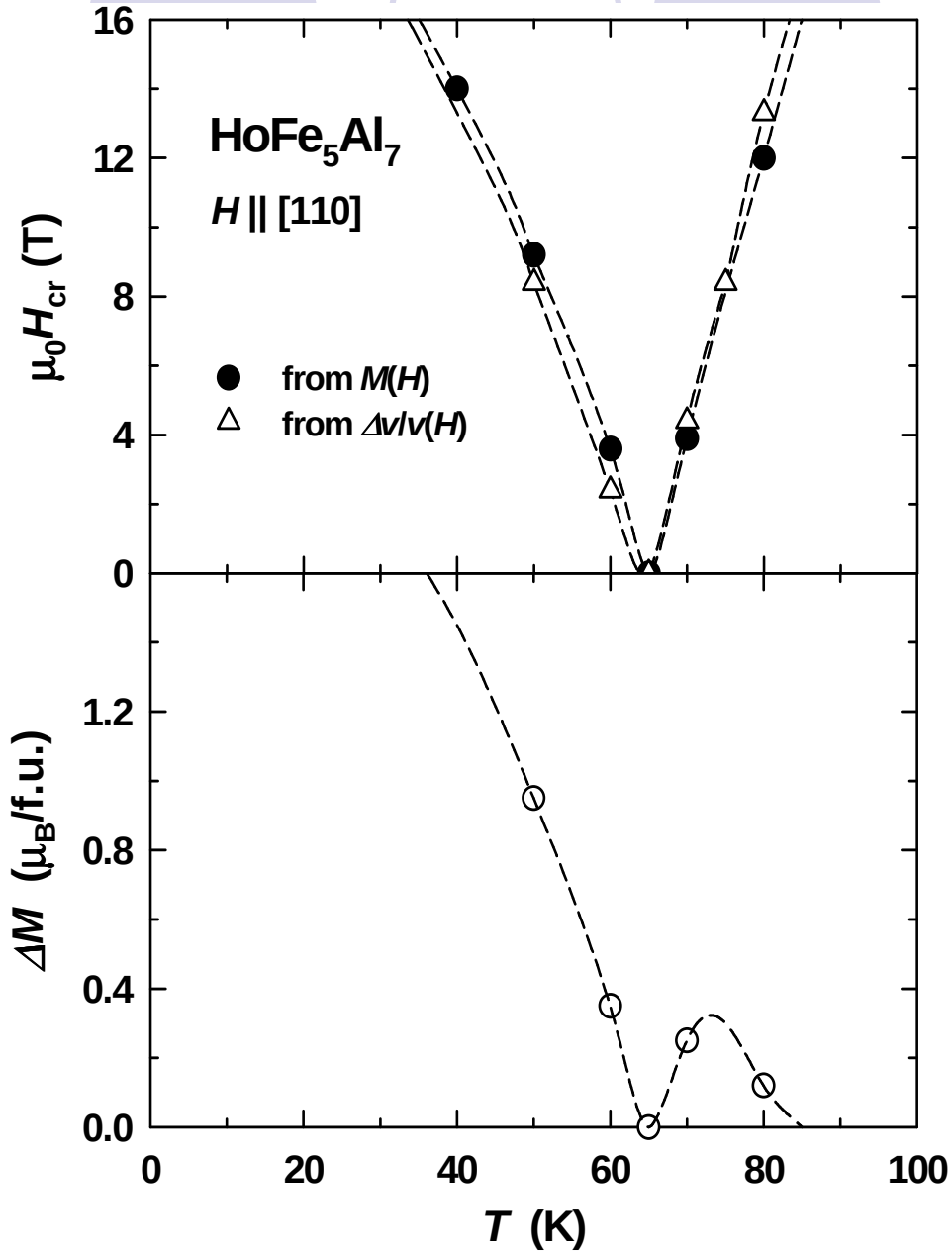
Magnetic transition appears along easy [110] axis

Magnetic transition along easy [110] axis

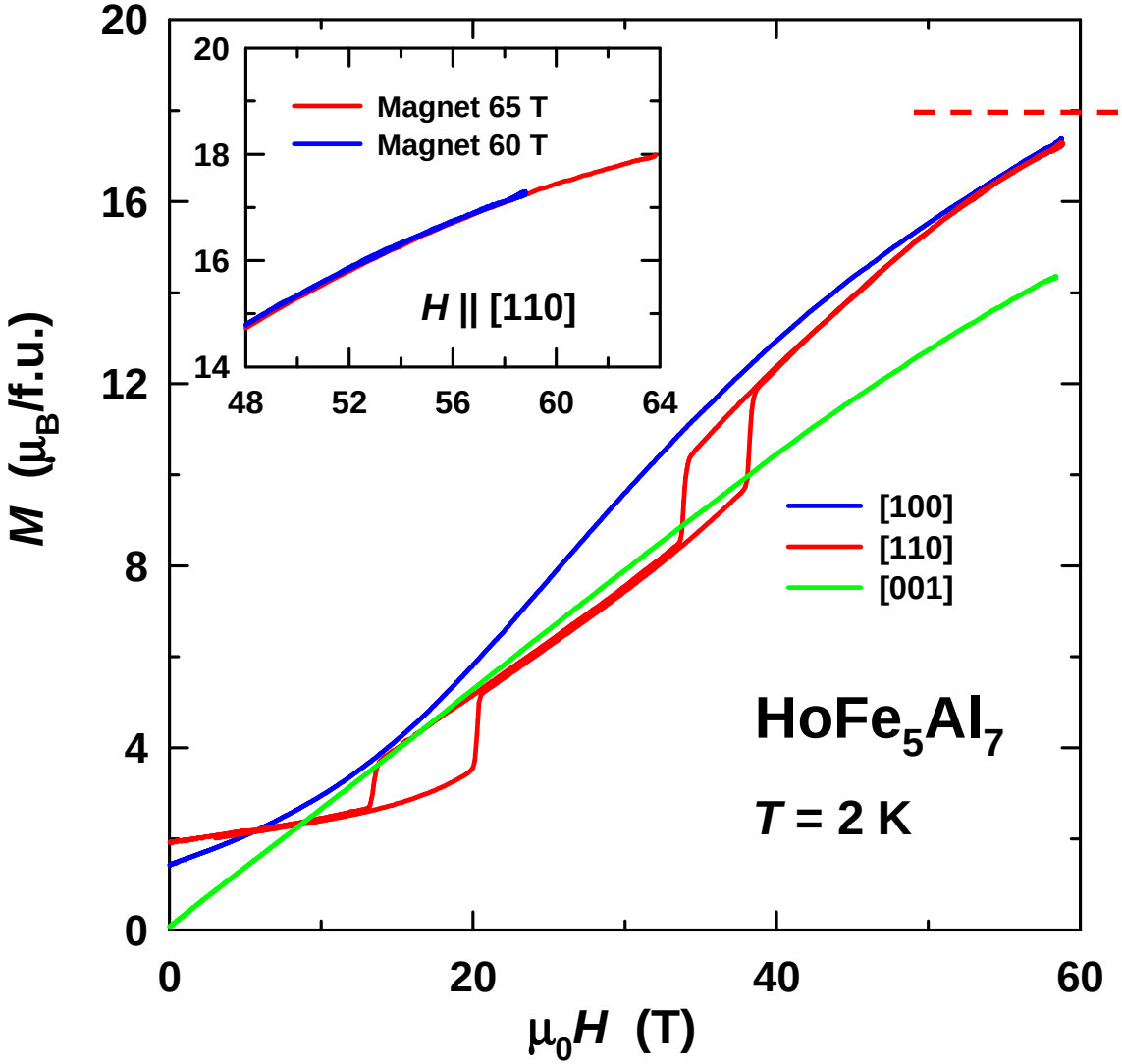


Magnetic transition along easy [110] axis





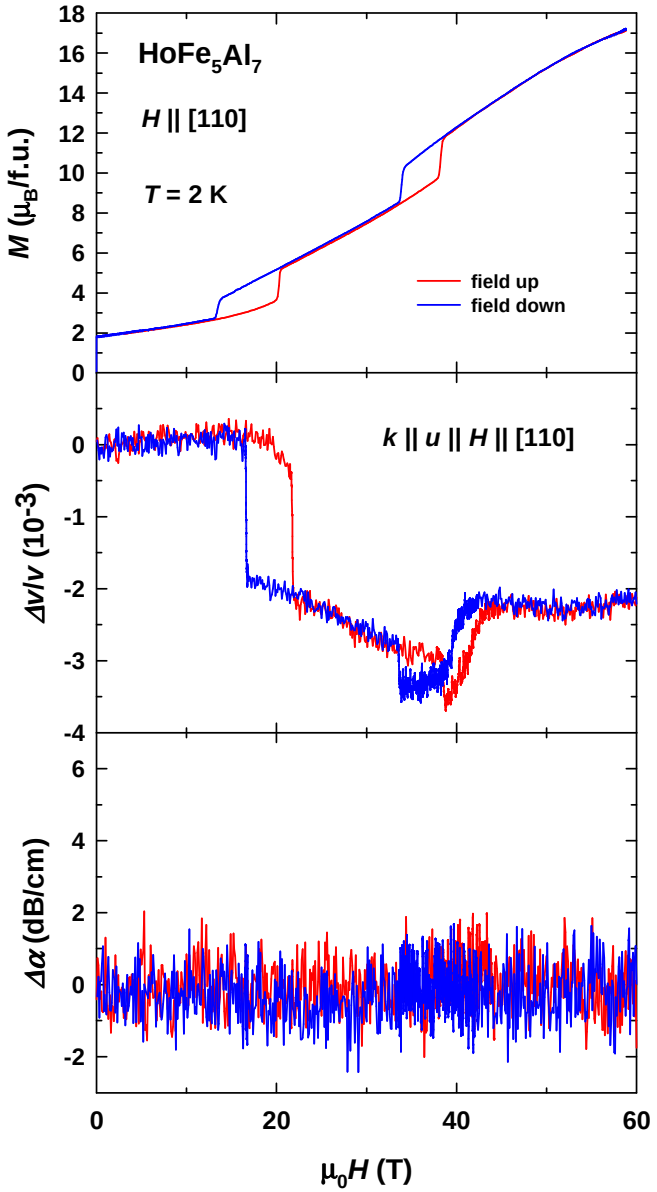
Magnetization curves in high magnetic fields



$M = M_{Ho} + M_{Fe} =$
$10 + 8 =$ **18 μ_B/f.u.**

TWO magnetic transitions along easy [110] axis

Magnetization and acoustic properties in high magnetic fields at T = 2 K



- Transitions look **similar**;

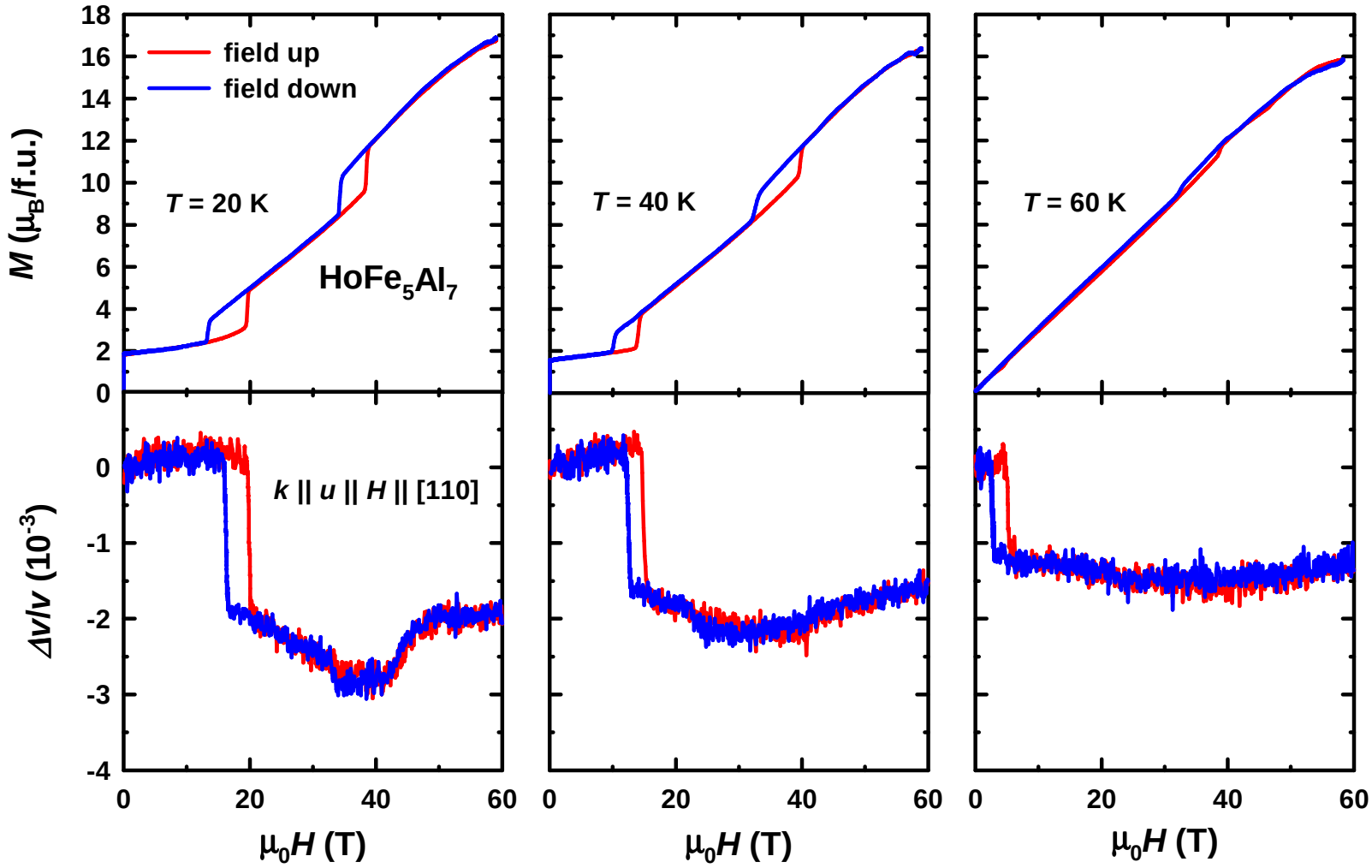
High sensitivity of sound velocity:

- **Different** shapes of transitions;
- **Different** nature of transitions?

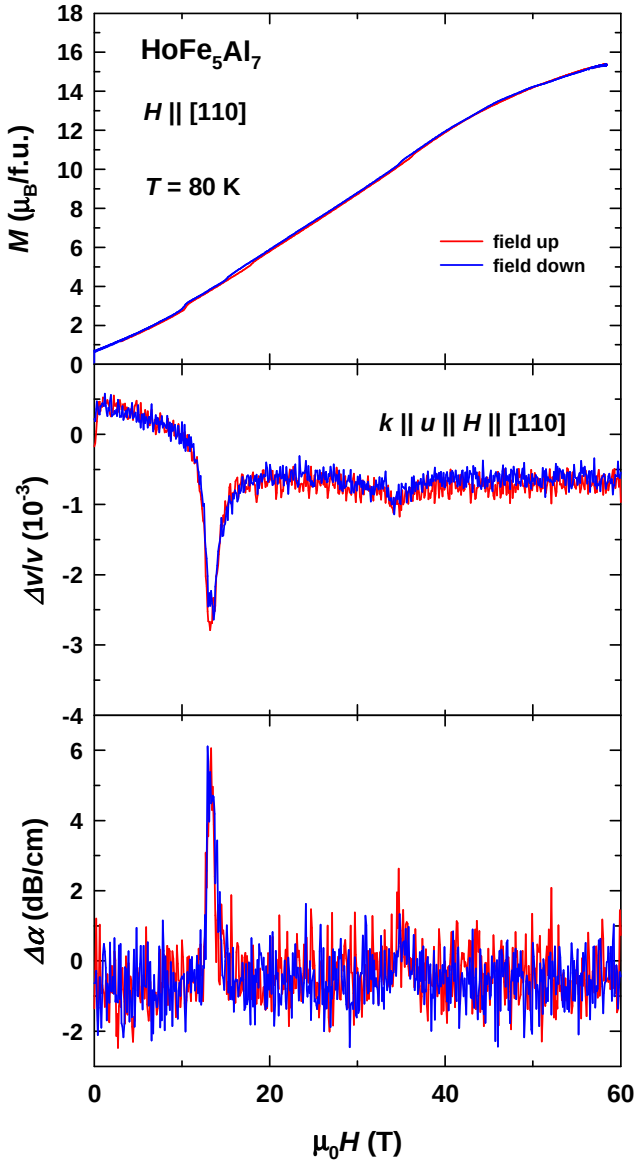
Strong noise:

- No transitions are seen.

Magnetization and acoustic properties in high magnetic fields at T = 20-60 K



Magnetization and acoustic properties in high magnetic fields at T = 80 K

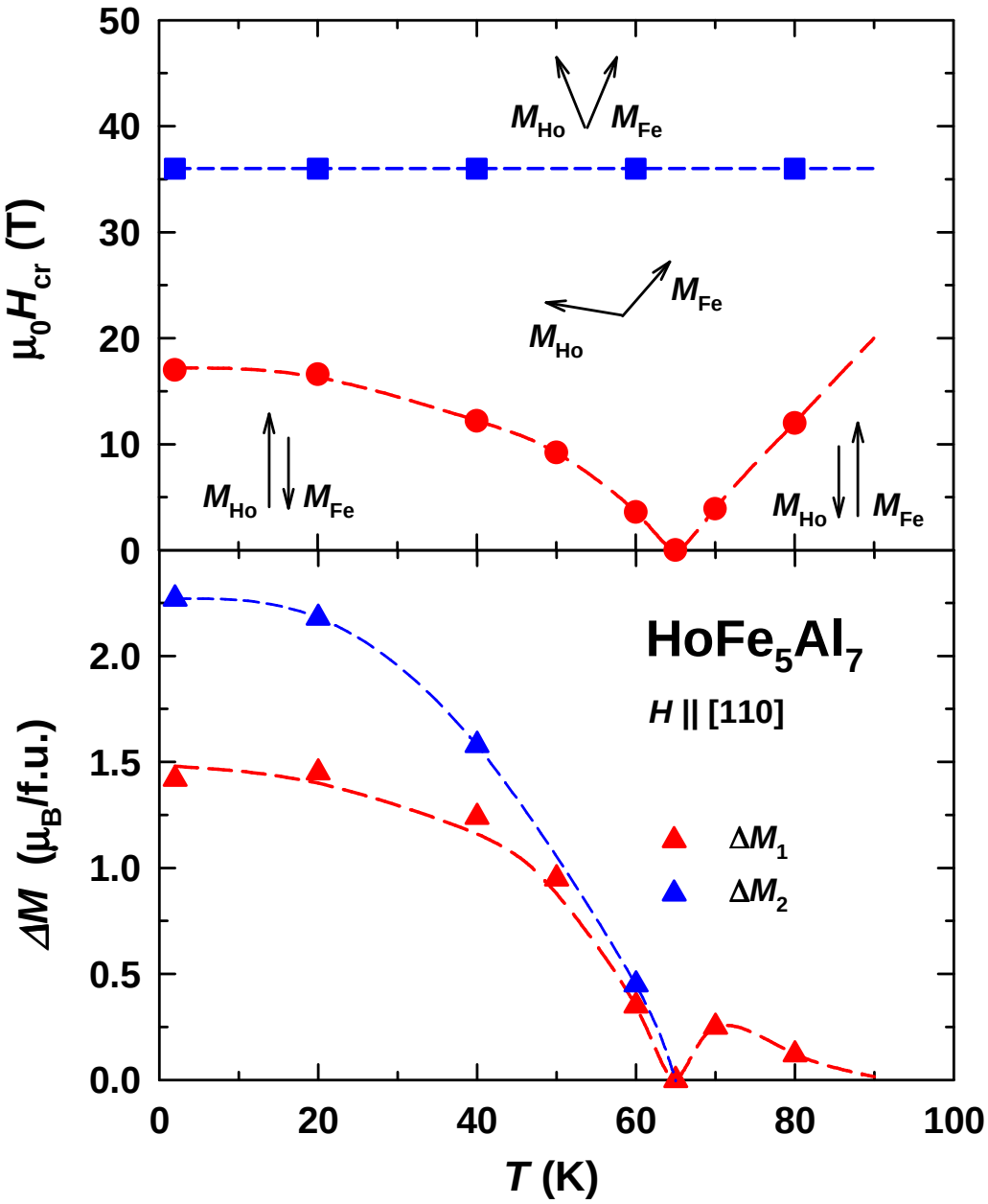


- **Very weak**, practically invisible anomalies;

High sensitivity of acoustic properties:

- **Very sharp** anomalies;

Magnetic phase diagram



Conclusions

Magnetization and magneto-acoustics of ferrimagnetic (T_C = 213 K) $HoFe_5Al_7$ single crystal in pulsed magnetic fields

- Strong **easy-plane anisotropy**;
- **In-plane anisotropy** between [100] and [110] axes;
- Two **field-induced magnetic transitions** along easy [110] axis; transition fields have **different** temperature dependences.

It is highly desirable to study $HoFe_5Al_7$ single crystal by neutron diffraction and/or synchrotron radiation in high magnetic fields

- **Nature** of transitions;
- Ho-Fe inter-sublattice **exchange interactions**.

Thank you for your attention!

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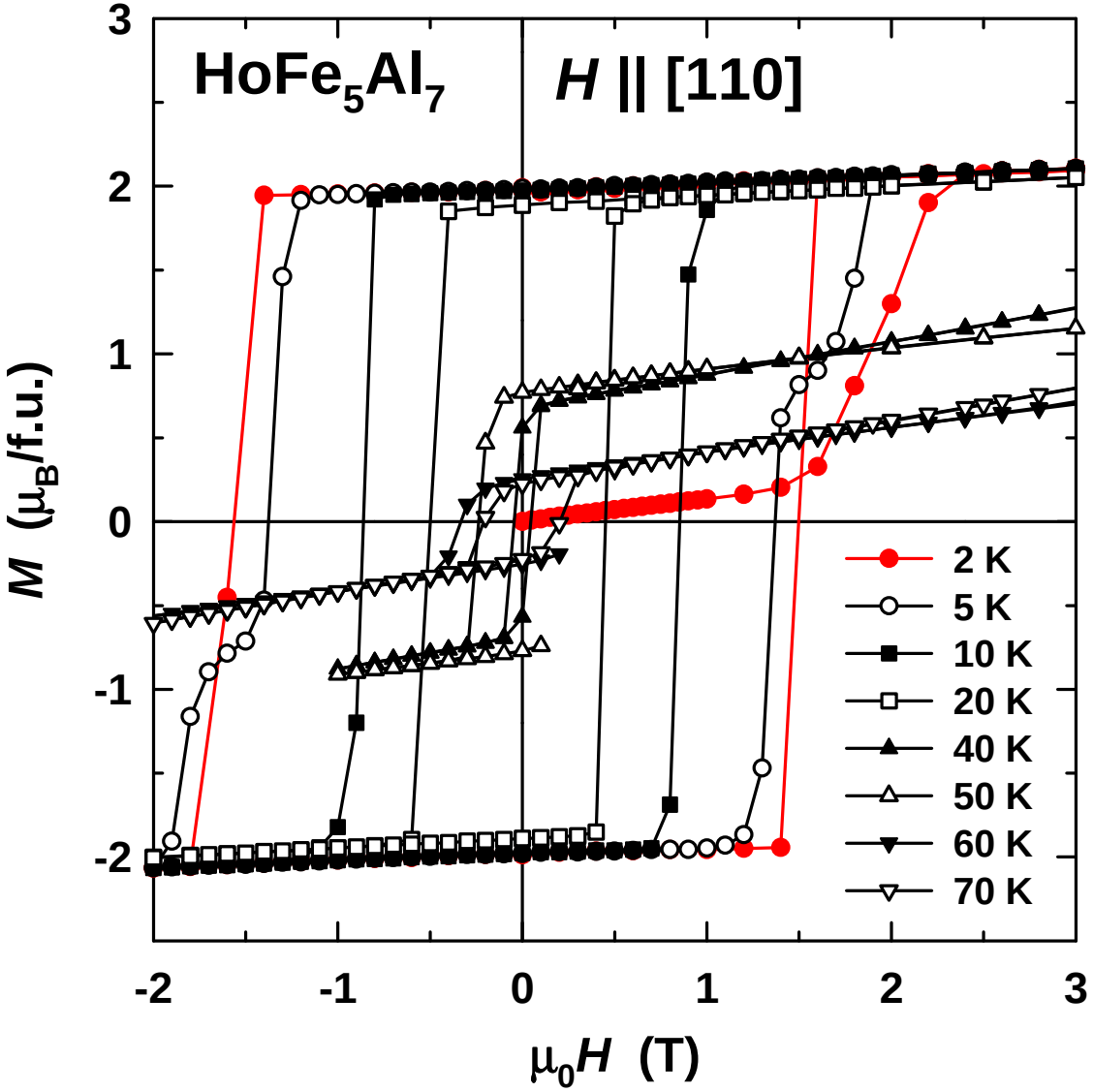
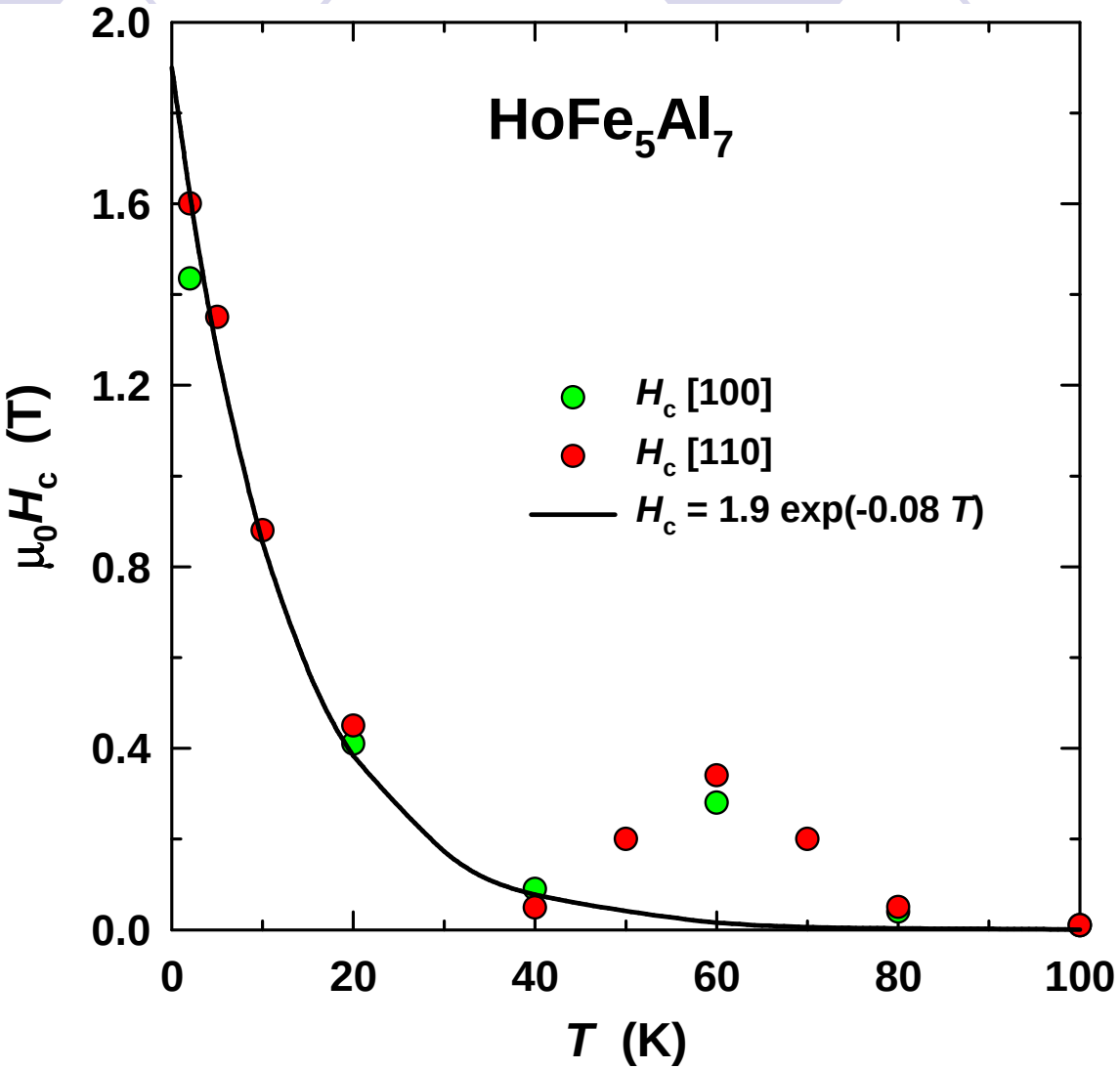
Hysteresis properties of $HoFe_5Al_7$



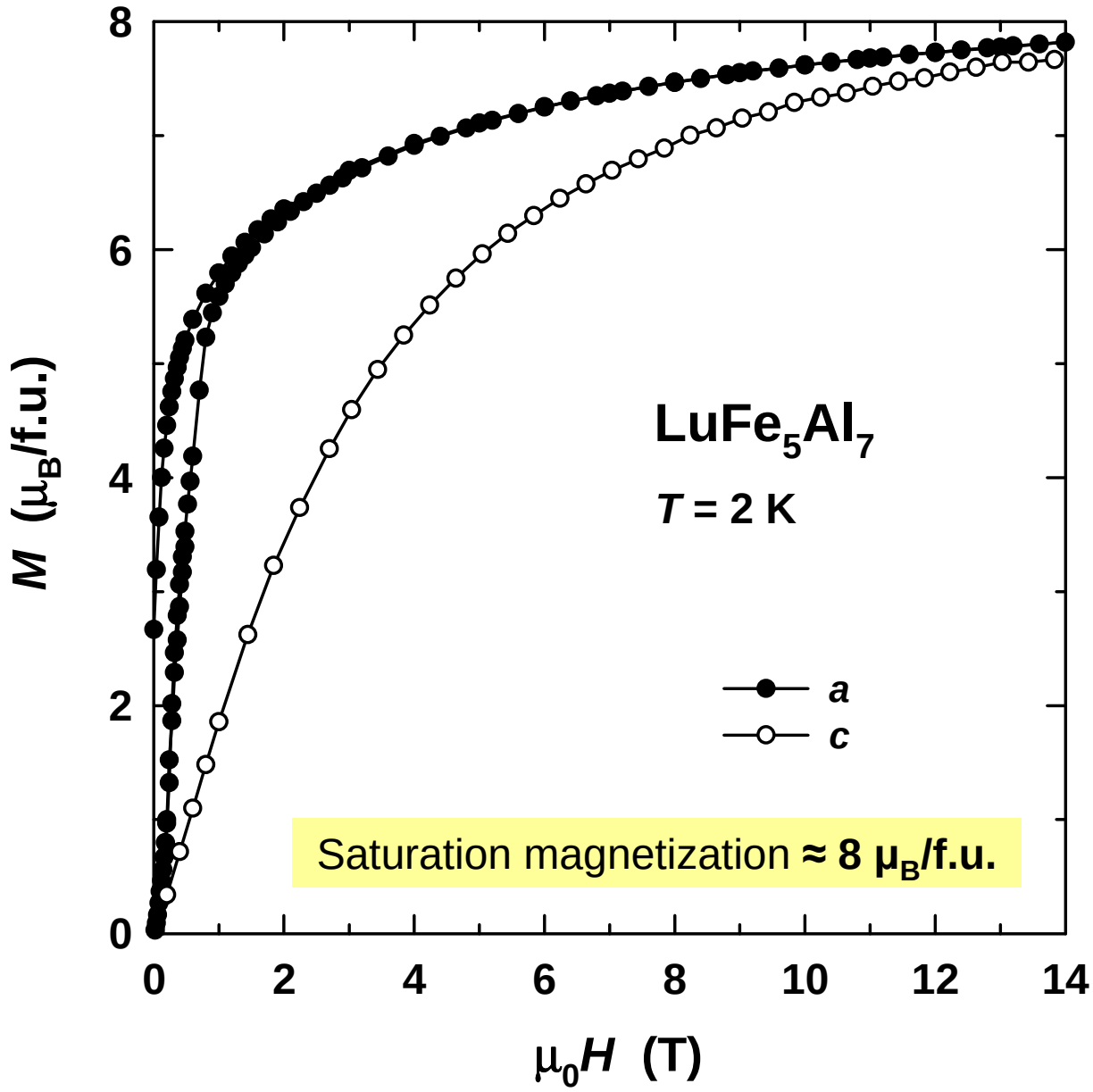
High coercivity at low temperatures

Temperature dependencies of coercivity of $HoFe_5Al_7$ along [100] and [110] axes



Exponential decrease in coercivity at low temperatures

Magnetization of Fe sublattice



$LuFe_xAl_{12-x}$: magnetic properties of Fe sublattice