Large Anisotropic Magnetoresistance and Magnetic Properties of Single Crystalline, $Tb_2Al_3Si_2$

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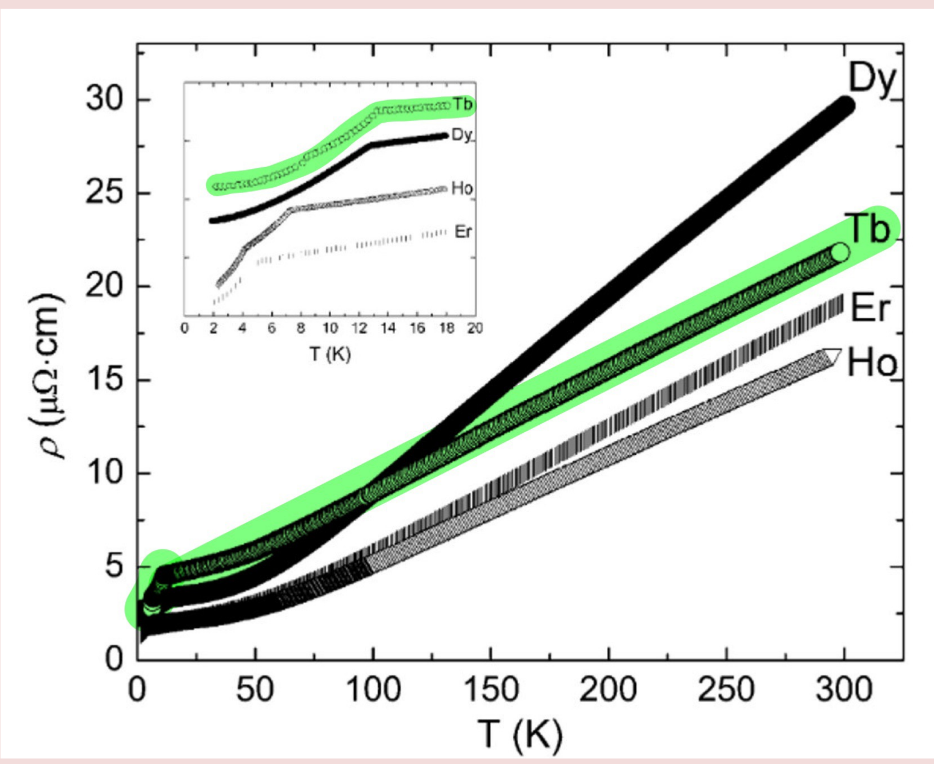
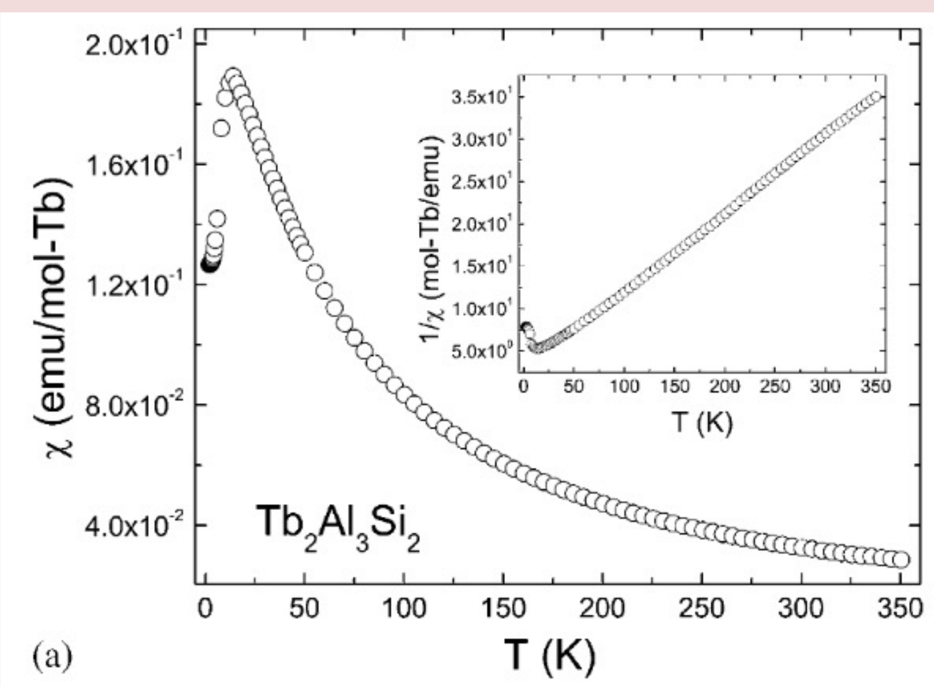
Abstract

Silicides hold significant scientific and technological relevance and have undergone extensive examination over the past few decades. Large magnetoresistance (LMR) materials, with their remarkable ability to exhibit substantial changes in electrical resistance in response to magnetic fields, are increasingly pivotal in various cutting-edge applications spanning from data storage technology to magnetic sensing and spintronic devices. The compound $Tb_2Al_3Si_2$ crystallize in the C-centered monoclinic YAl_3Si_2-type, which contains wavy layers of Al and Si atoms linked together by additional Al atoms and linear Si-Al-Si bonds, has been reported to show antiferromagnetic order below T_N~16 K. However, there is a lack of extensive data concerning its magnetic and transport characteristics. In response to this deficit, we grew high-quality single crystals through the self-flux method, resulting in needle-shaped formations. Magnetic and transport measurements were carried out with the magnetic field aligned parallel and perpendicular to the needle's presumed direction along the b-axis. Due to the low symmetry (monoclinic), the orientation of the a- and c-axes to the magnetic field remained undetermined. Detailed temperature and field dependent magnetic and transport results exposed a pronounced magnetic anisotropy in the system. Notably, transport measurements unveiled a substantial anisotropic magnetoresistance (AMR) as well as a LMR in $Tb_2Al_3Si_2$. We will delve into a thorough discussion of the aforementioned results to provide a comprehensive understanding of the compound's properties.

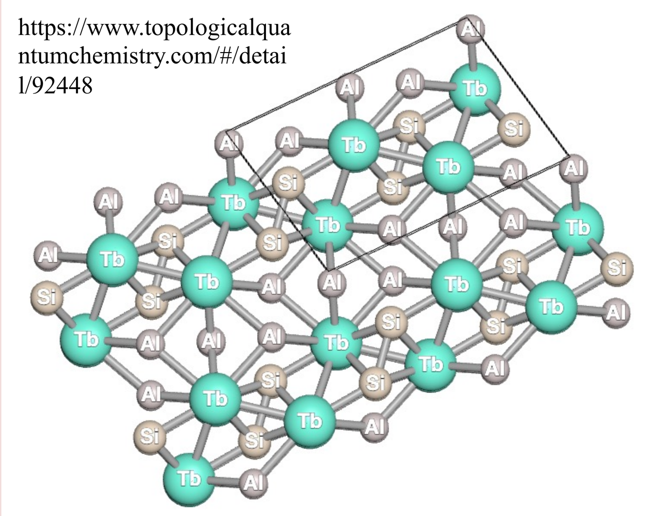
Background



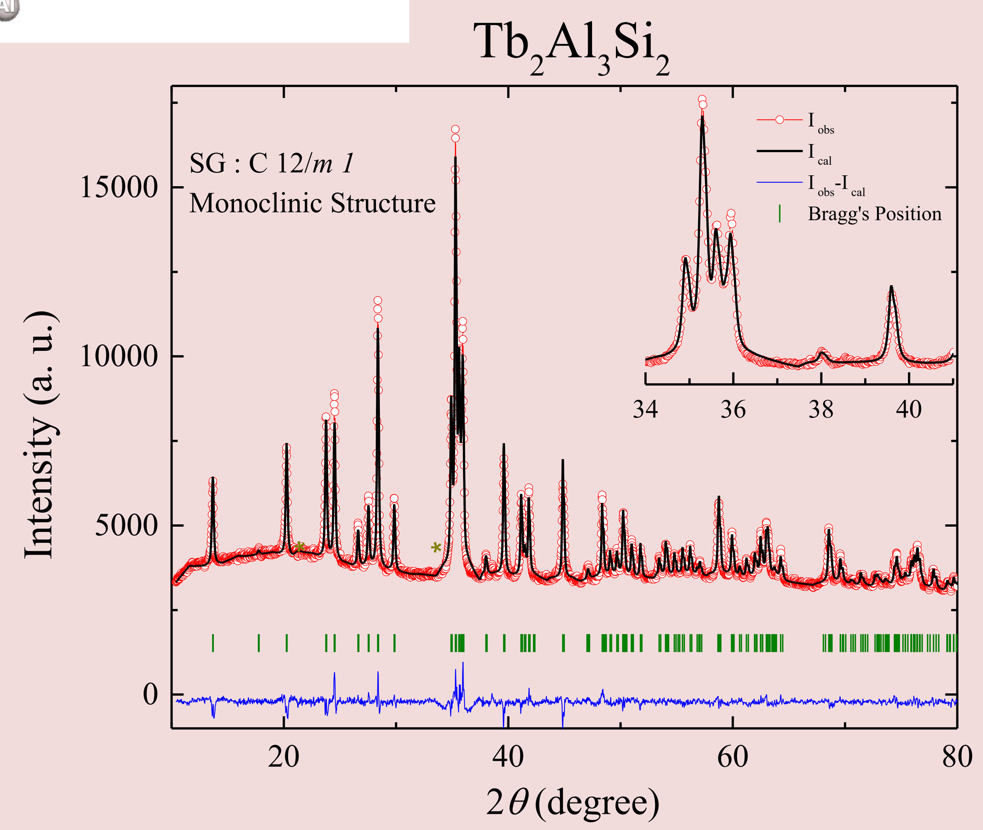


Results

Crystal Structure: X-ray Diffraction



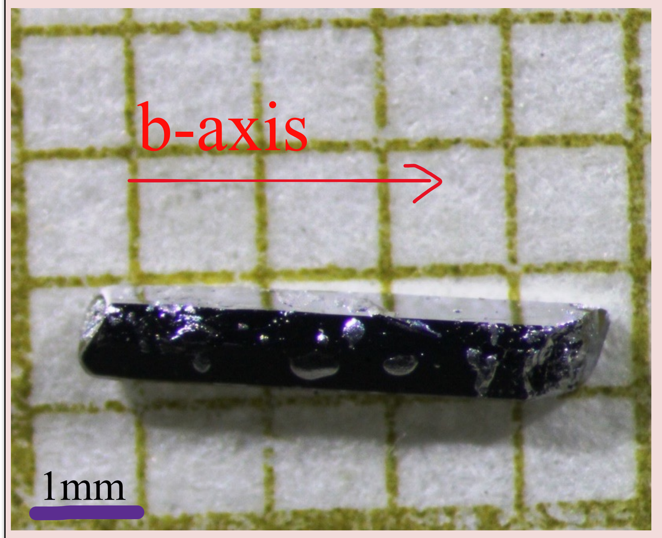
- Crystal Structure of $Tb_2Al_3Si_2$

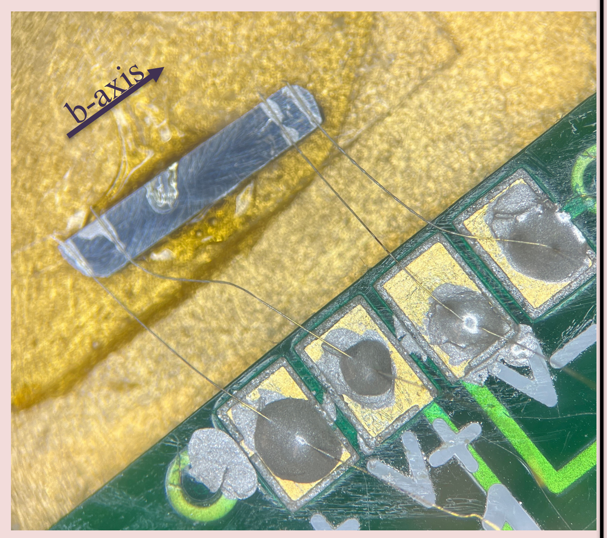


- Rietveld Refinement of X-ray Powder diffraction

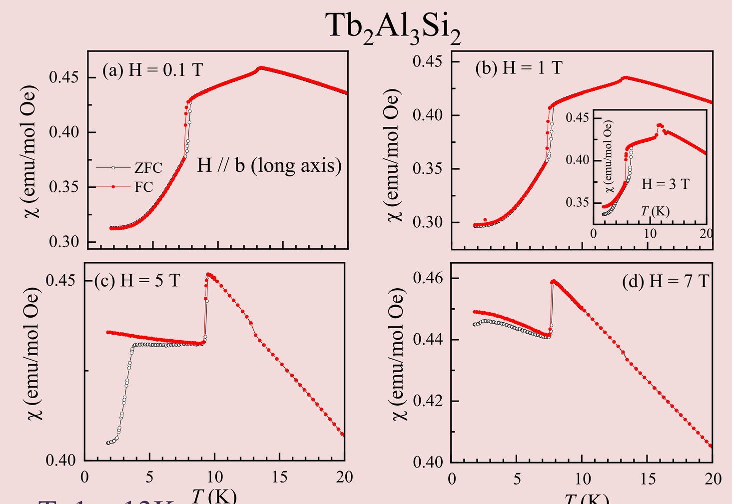
Name		x	y	z	occ.
Tb	4	0.61905(14)	0.00000(0)	0.32200(21)	0 .473(0) ~ 0.50
Si	4	0.90435(54)	0.00000(0)	0.35971(80)	0.483(0) ~ 0.50
Al	2	0.00000(0)	0.00000(0)	0.00000(0)	0.259(0) ~ 0. 25
Al	4	0.30098(63)	0.00000(0)	0.12840(84)	0.515(3) ~ 0. 50

Lattice parameters:
a=10.179(1) Å, b=4.038(1) Å , c= 6.600(2) Å and α = γ = 90 °, β= 101.2° (1)



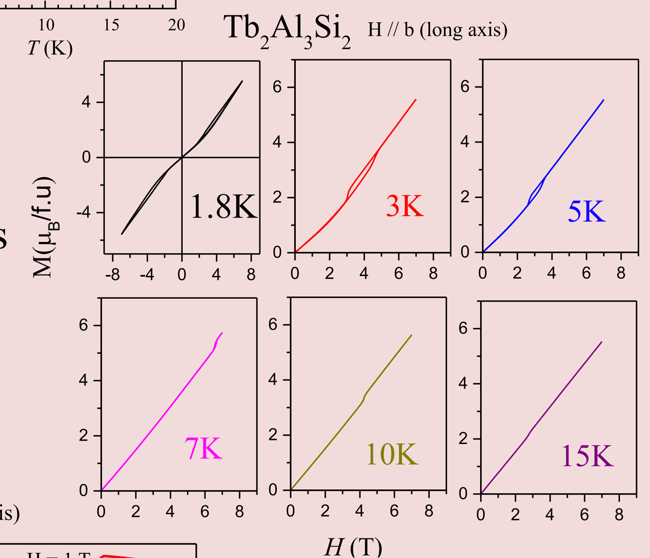


Magnetic Properties

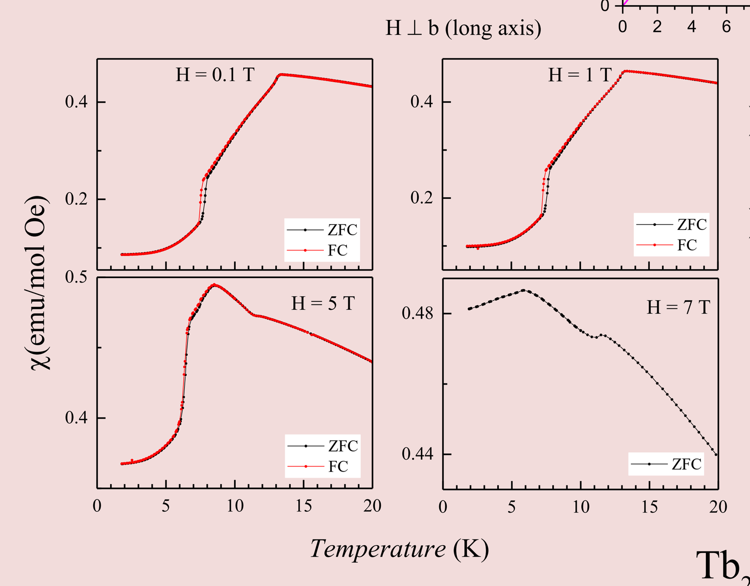


Tn1 ~ 13K
Tn2 ~ 8K

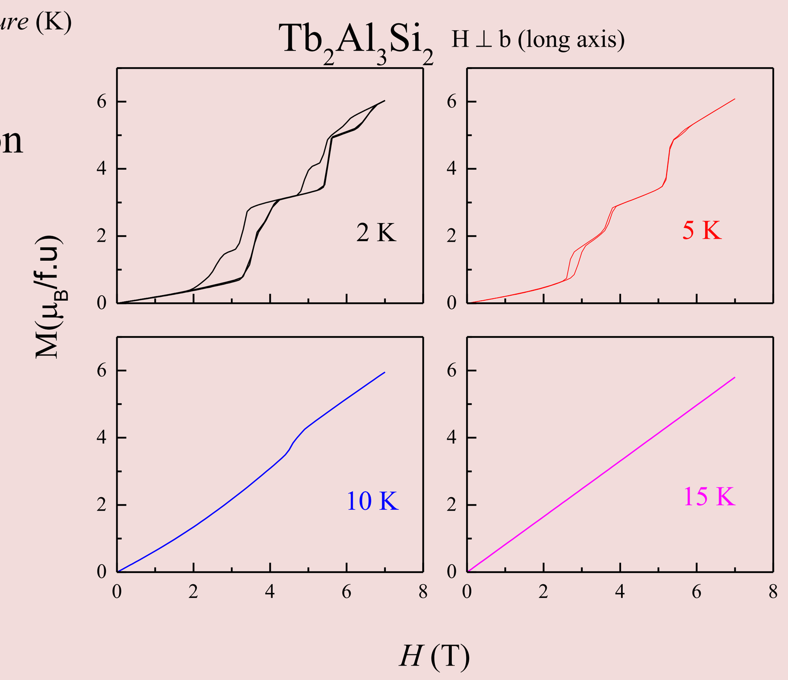
- Spin Glass feature as there is bifurcation of ZFC and FC
- We see two transition temperatures in this orientation of the magnetic field



- We see hysteresis which shifts towards low fields as we increase the temperature showing complexity of magnetic structure

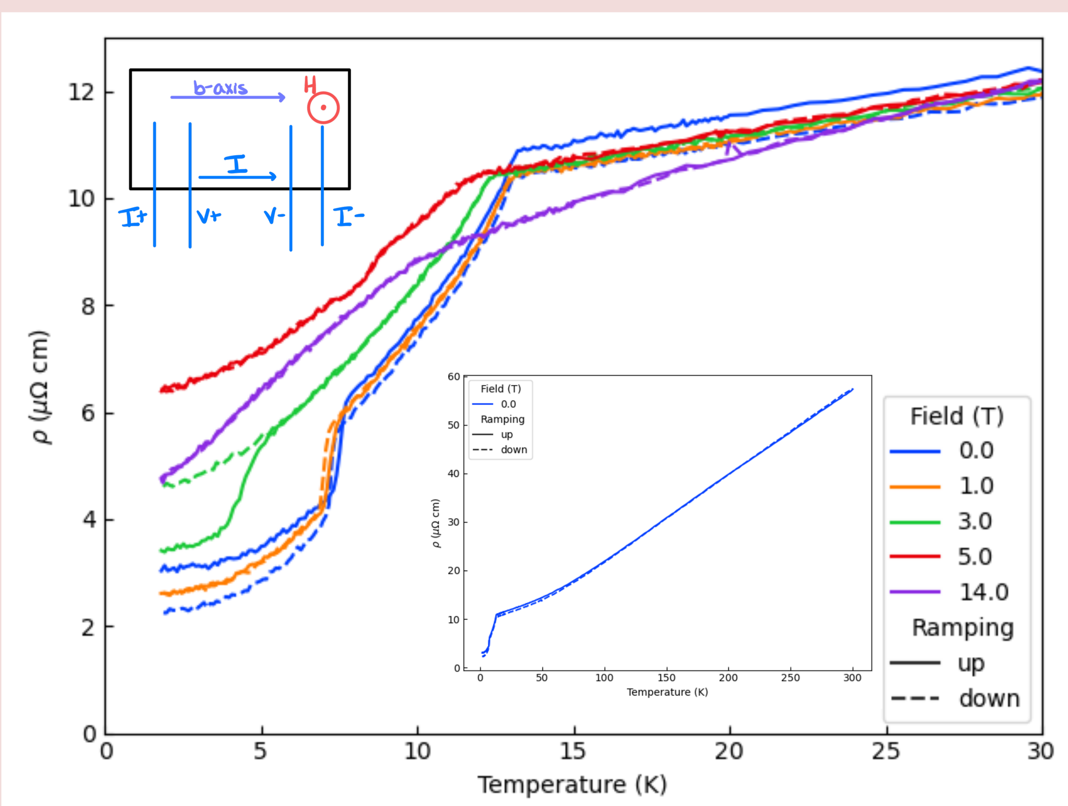


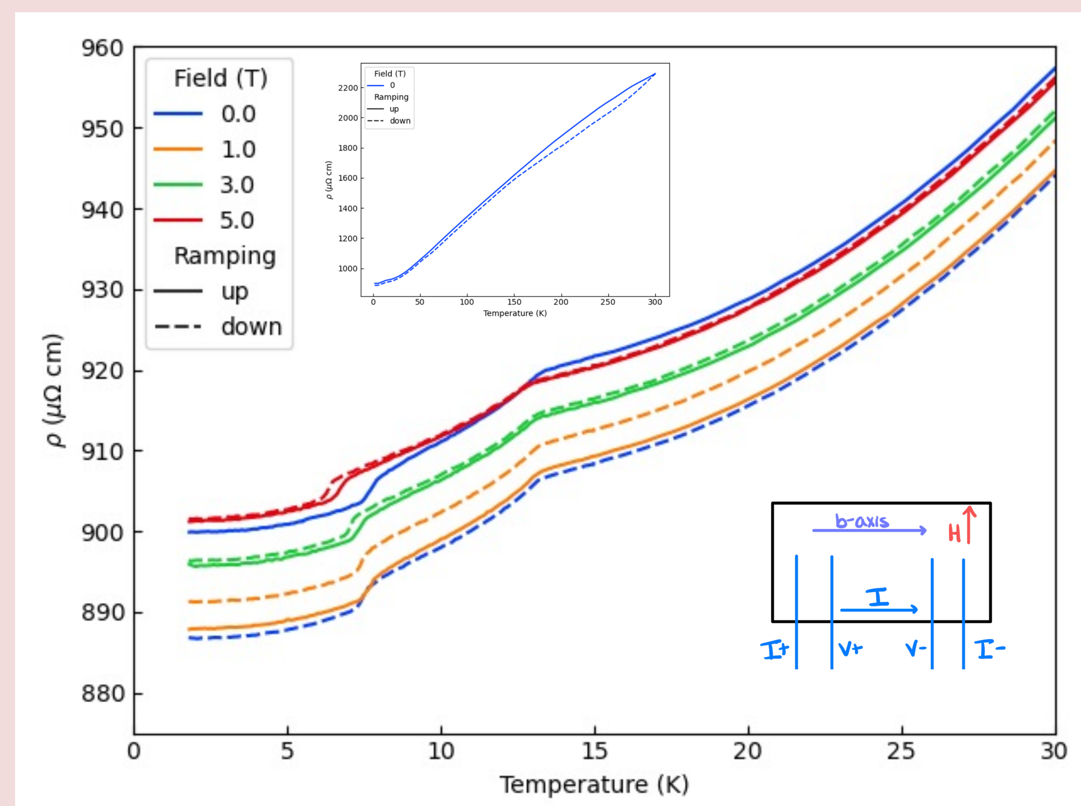
- No bifurcations in this orientation
- We still see two transition points around the same temperature points



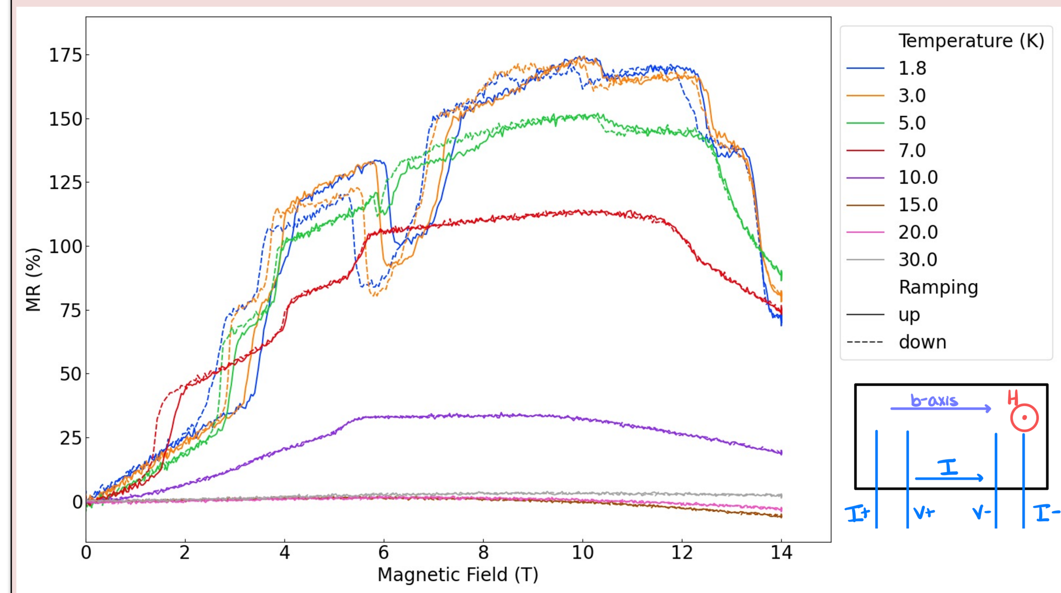
- We see a more complex magnetization as a function of field
- We see that this complex structure is highly temperature dependent
- We see hysteretic behavior

Transport Properties: Resistivity

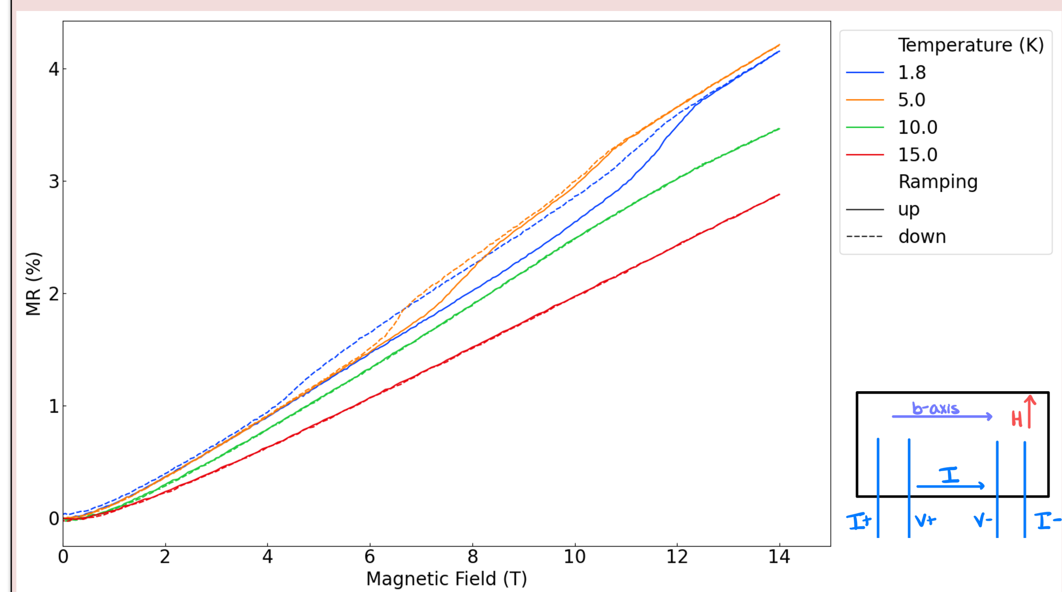




Results: Magneto-Resistance



$$MR(\%) = 100 * \frac{R(H) - R(0)}{R(0)}$$



Conclusions

- We grew large single-crystals of $Tb_2Al_3Si_2$
- Using x-ray diffraction and Rietveld Refinement to determine the monoclinic structure of $Tb_2Al_3Si_2$
- Using Laue diffraction, we were able to determine the direction of the facet on the crystals
- We studied complex magnetic properties showing the temperature and external field dependence of them
- We show the orientation dependence of transport measurements. We see a difference of two orders of magnitude between the resistivity.
- We show a complex non-linear MR in one orientation.
- We show large anisotropic MR in $Tb_2Al_3Si_2$. First direction shows a maximum of 175% MR, while the second shows small linear MR reaching a maximum of 4%.