

Hall Coefficient of Chromium, Part II

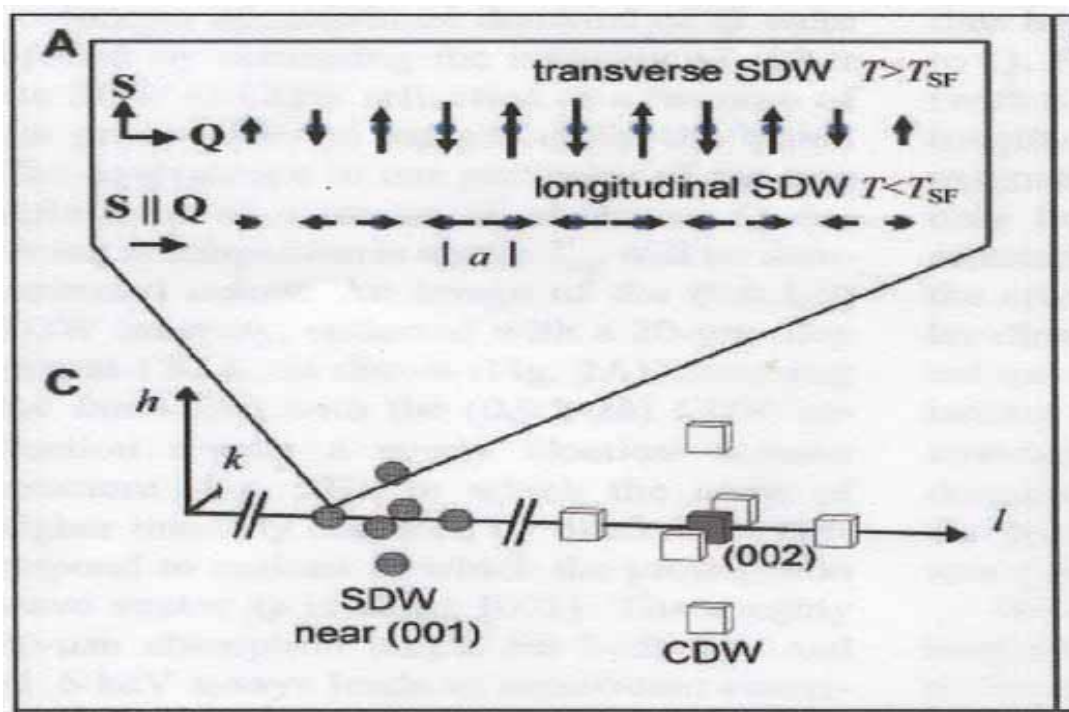
Rafael Jaramillo

Rosenbaum Lab

P-335 Project

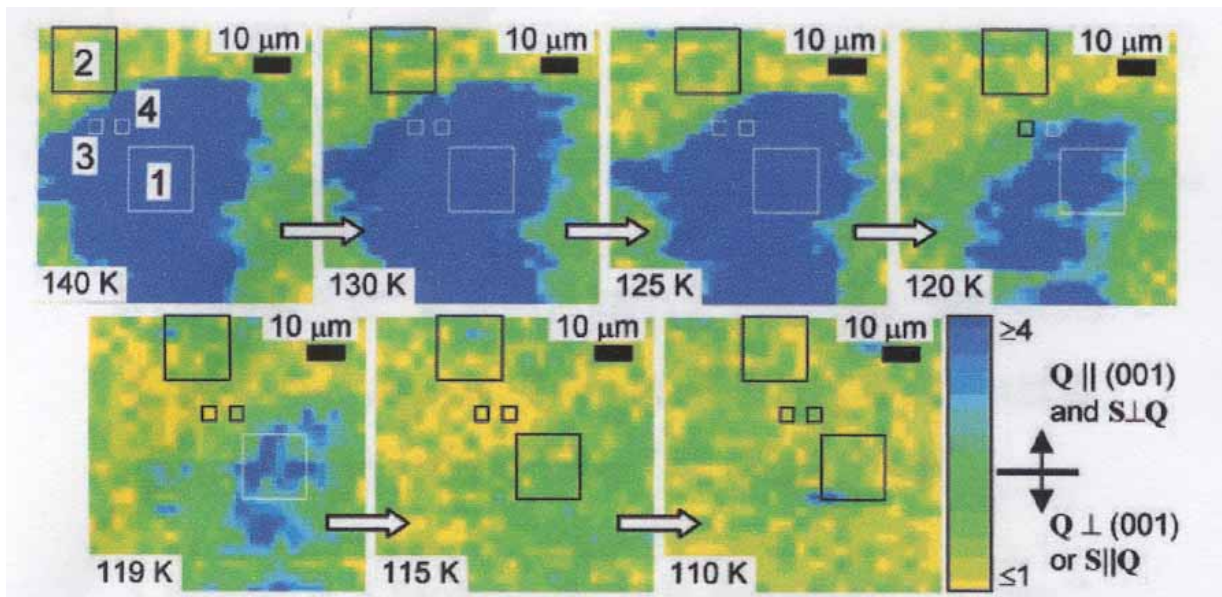
Antiferromagnetism and Chromium

- Transition element; BCC crystal; Electronic structure $[\text{Ar}] 3d^5 4s^1 \rightarrow ^7S_3$
- Para-Antiferromagnetic transition at $T_{\text{Neel}} \approx 311 \text{ K}$
 - Non-commensurate SDW with wave-vector $Q = (0, 0, 1 \pm)$
- Spin-flip transition at $T_{\text{SF}} \approx 123 \text{ K}$
- Well suited for studying quantum fluctuations and phase transitions



Probing Chromium

- X-Ray and Neutron Diffraction
 - Sharing samples with Eric Isaacs; X-ray diffraction images at APS



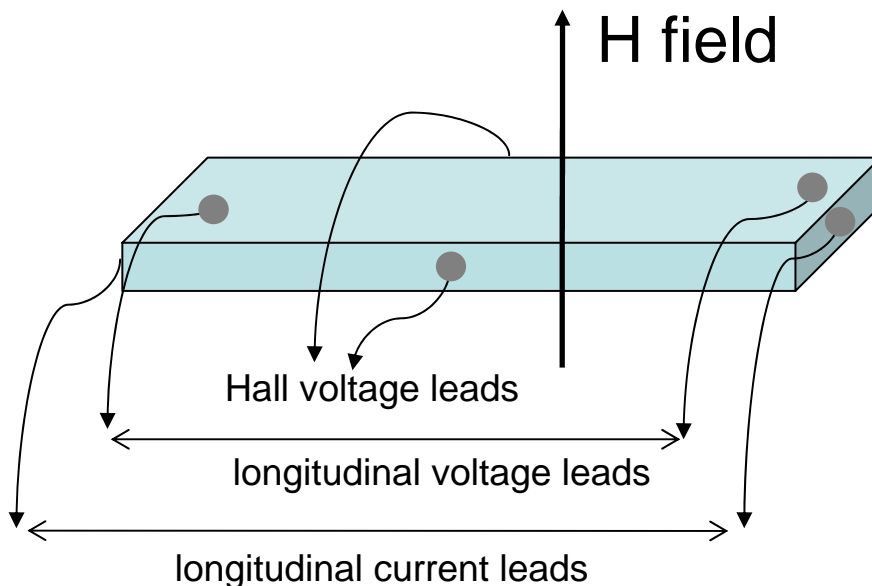
E. Isaacs et al.

- Hall coefficient measurements: $R_H(T)$

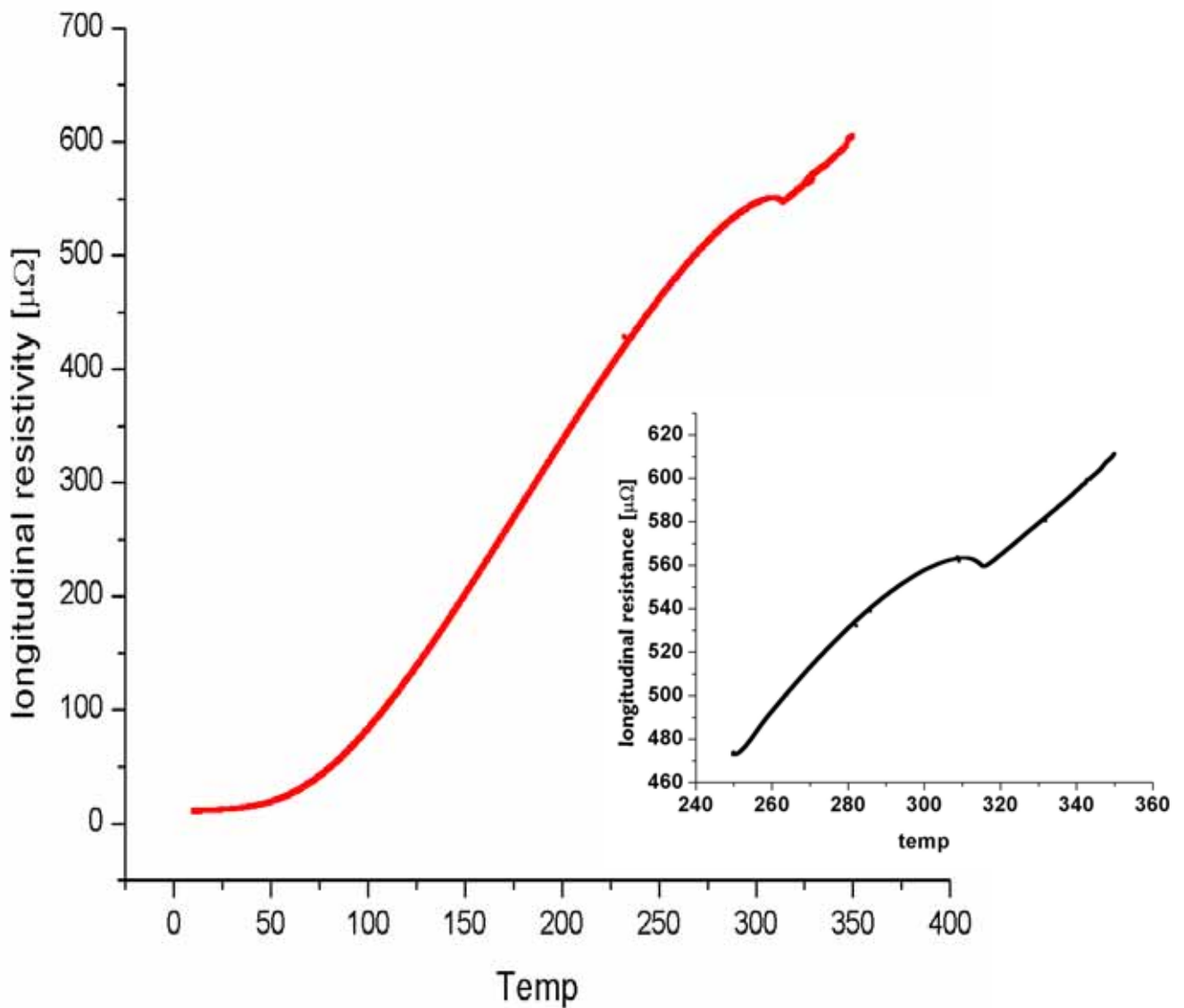
$$R_H = \frac{E_y}{J_x H_z} \quad \left(\frac{1}{nec} \right) \text{ — single band model}$$

Measuring Hall Resistance

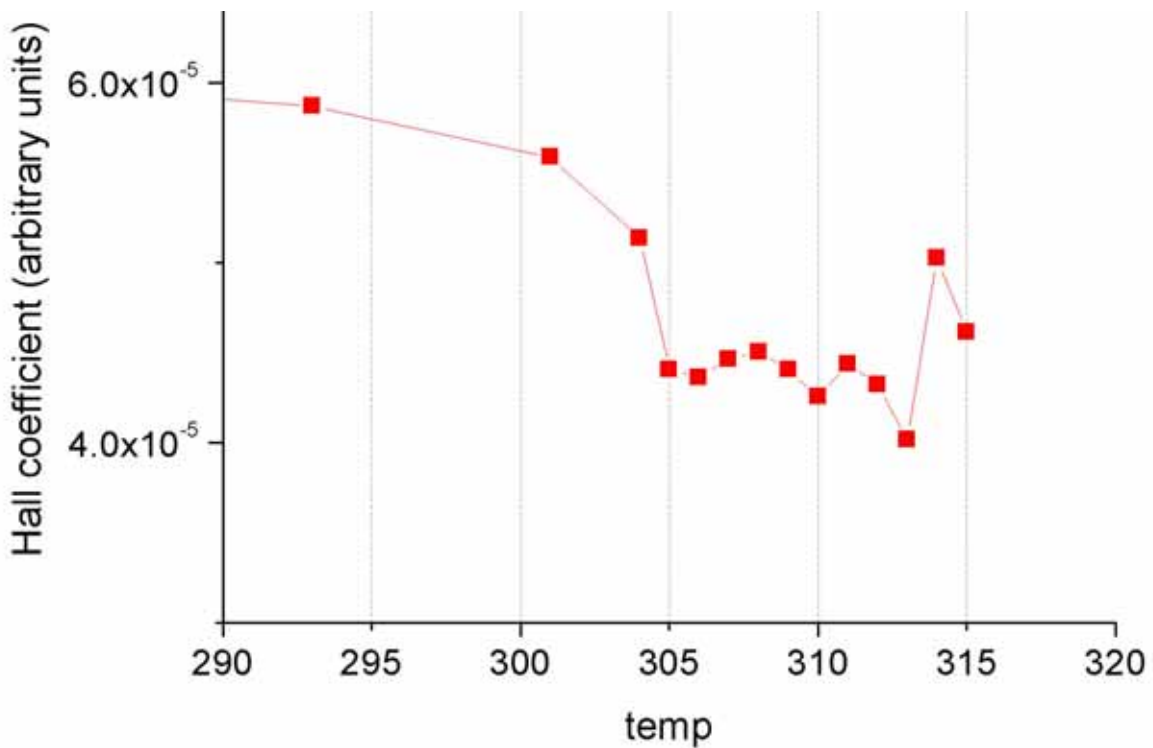
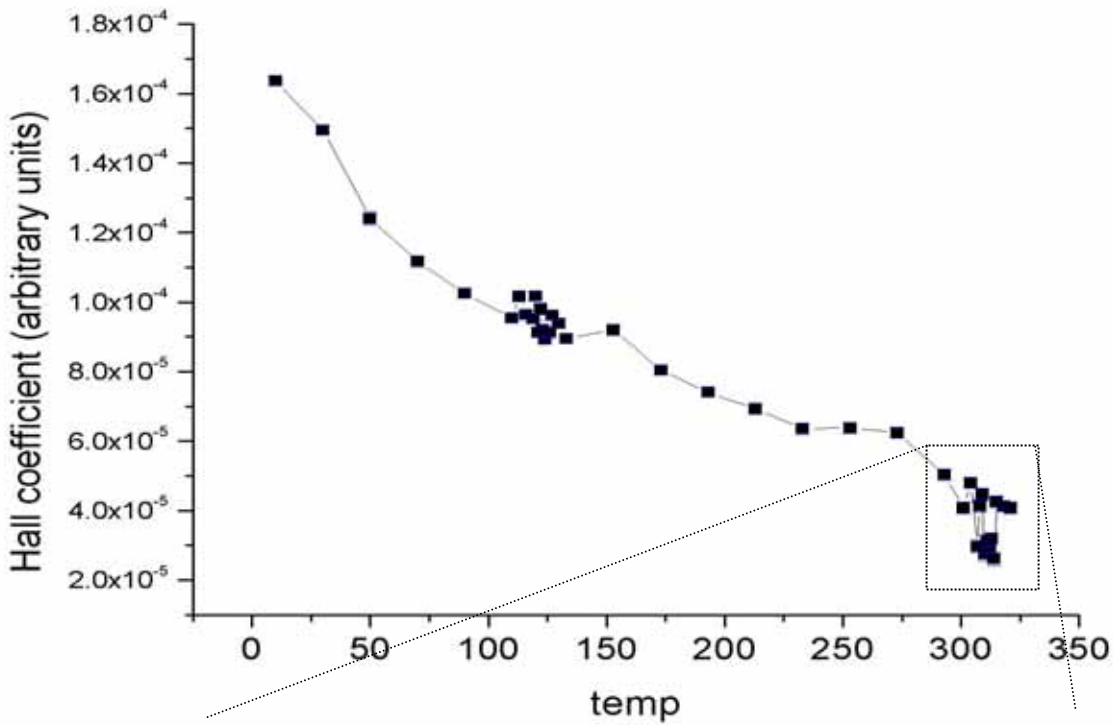
- Sample dimensions 12x5x2 mm
- Quantum Design MPMS system
 - He⁴ cooled; 1.9 - 400 K temperature range
 - 5 T maximum field
- Resistance measured by AC resistance bridge
 - 20 V, 17 Hz excitation



Longitudinal Resistance: Visualizing T_{Neel}

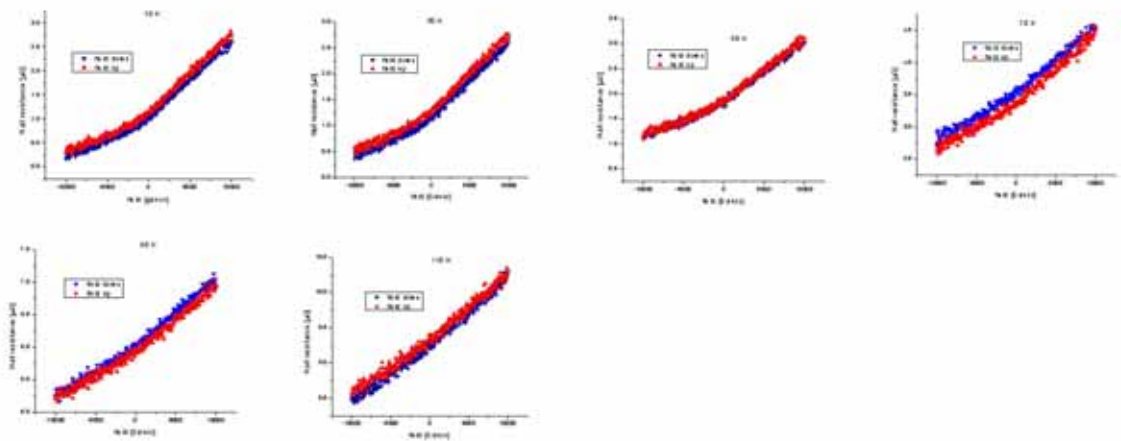


Data: Hall Coefficient vs. Temperature

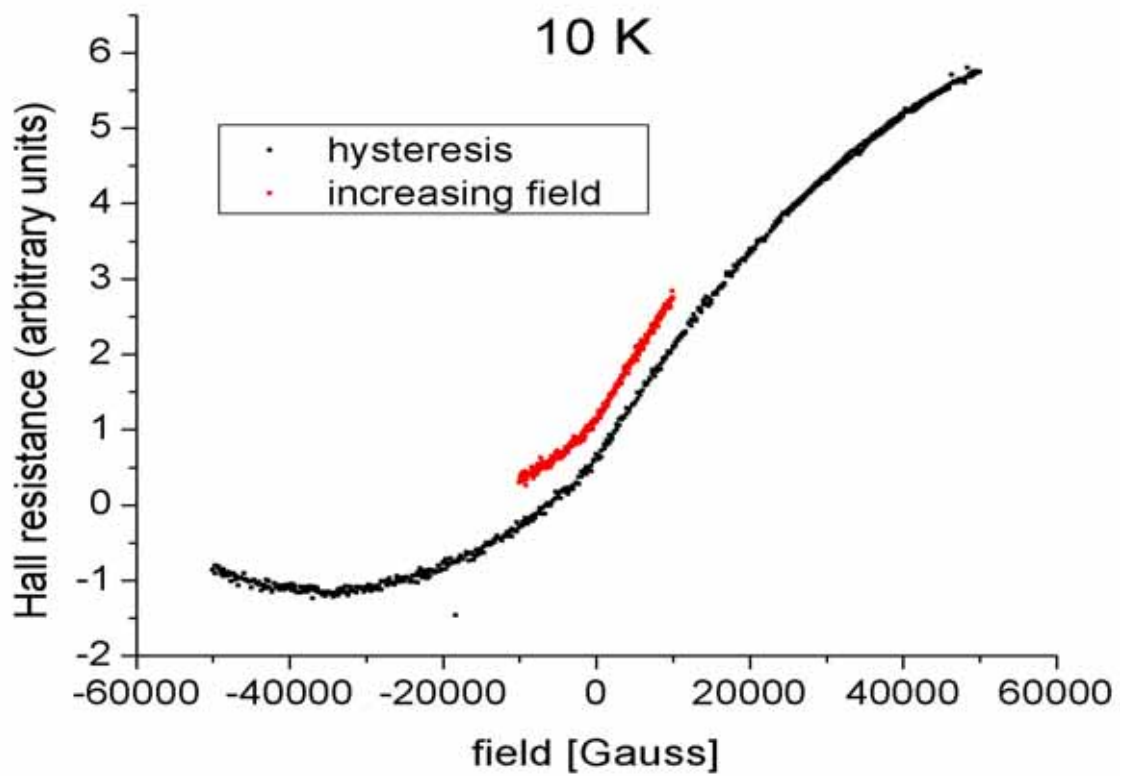


Focus on Asymmetry of Hall Resistance

- Increasing vs. decreasing field scans overlap:



- No perceptible hysteresis:

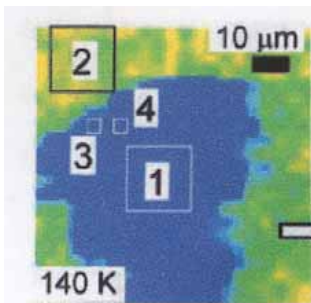


Hall Measurements on a Single-Q Sample

- Finite domain-size effects vs. correlated electron (magnetic ordering) effects
 - i.e. Is Hall resistance asymmetry caused by domain wall pinning?
- Field-cooling of single-crystal sample: yields a 60 - 90% single-domain magnetic order
 - Q aligns with cooling field H; 5 T field should suffice
 - Requires a good-quality sample of known orientation

Alternate Method: Small Samples

- Individual domains $\approx 60 \text{ nm}$
Samples on same scale should exhibit single-domain behavior
- Small-sample advantages and disadvantages:
 - More reliable field-cooling
 - More difficult resistance measurement; van der Pauw 4-probe method required
 - Preparation of microscopic samples

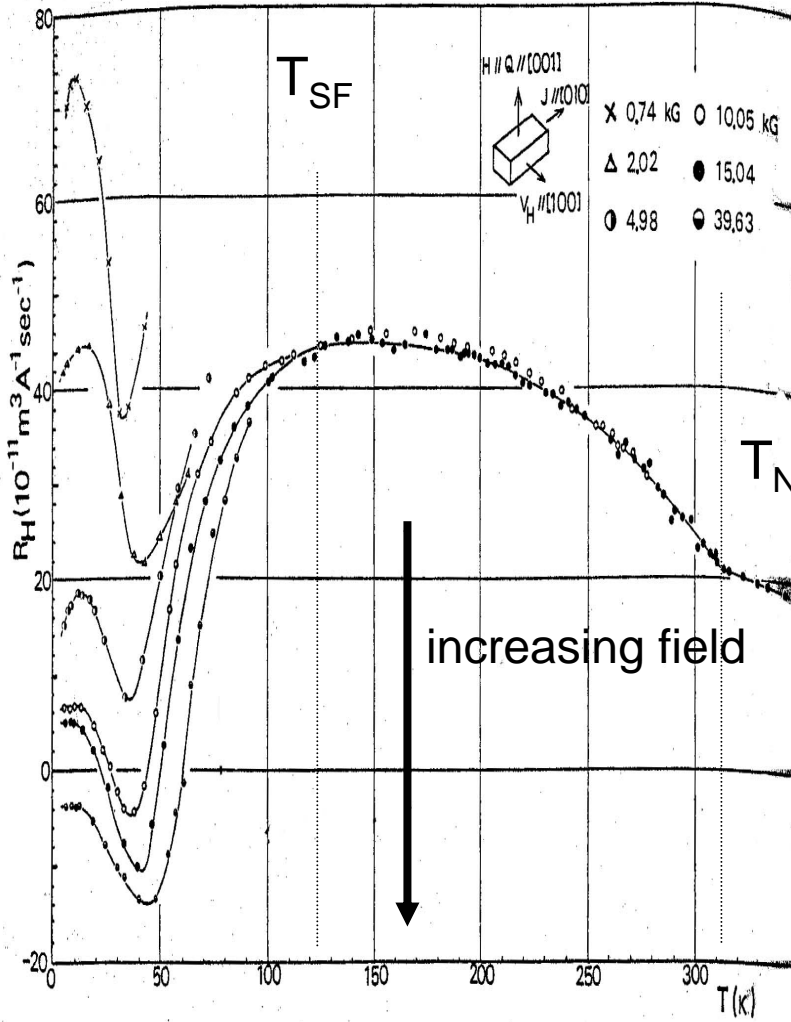


Scale of individual domain
(Isaacs et al.)

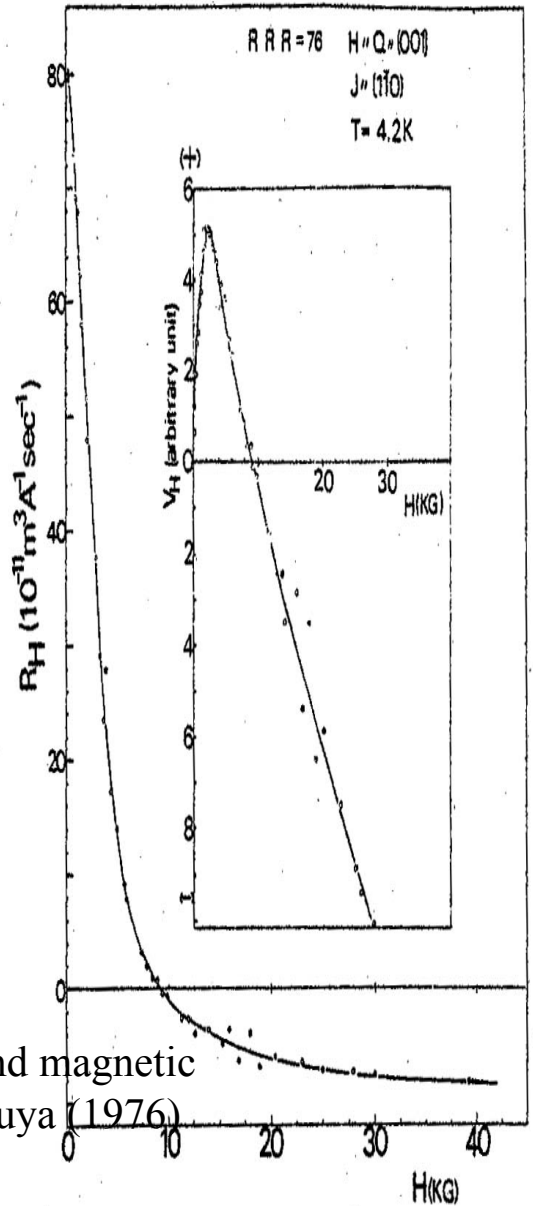
Derailment: MPMS



Comparison with Published Results



Hall coefficient as a function of temperature and magnetic field; $H \parallel [001]$, $Q \parallel J \parallel [010]$, $V_H \parallel [100]$; Furuya (1976)



Hall data as a function of magnetic field at 4.2 K; $H \parallel Q \parallel [001]$, $J \parallel [110]$, $V_H \parallel [110]$; Furuya and Mitsui (1976)

Current Status & Next Steps

- MPMS recently returned to service
- New macroscopic sample: same dimensions, but more reliable single-crystal orientation
 - Field-cooled and non-field-cooled Hall measurements
- New microscopic sample
- Two (magnetic) axis system?
 - Various orientations of Q , J , and H

Selected References

- Arrott and Werner, “First-Order Magnetic Phase Change in Chromium at 38.5°C”, *Phys. Rev. Lett.* **14**: 1022-1024 (1965)
- P.G. Evans, E.D. Isaacs, et Al., “X-ray microdiffraction images of antiferromagnetic domain evolution in chromium”, *Science* **295**: 1042-1045 (2002)
- E. Fawcett, “Spin-density-wave antiferromagnetism in chromium”, *Rev. Mod. Phys.* **60**: 209-283 (1988)
- Y. Furuya, “Temperature and Magnetic Field Dependence of the Hall Coefficient on the Antiferromagnetic Chromium”, *J. Phys. Soc. Jap.* **40**: 490-497 (1976)
- Y. Furuya and T. Mitsui, “Magnetic Field Dependence of the Hall Coefficient in Low Temperature on the Antiferromagnetic Chromium”, *J. Phys. Soc. Jap.* **41**: 1938-1941 (1976)