BIDIRECTIONAL CHARGE-DENSITY-WAVES IN QUASI-TWO-DIMENSIONAL RARE EARTH TRITELLURIDES

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Outlook:

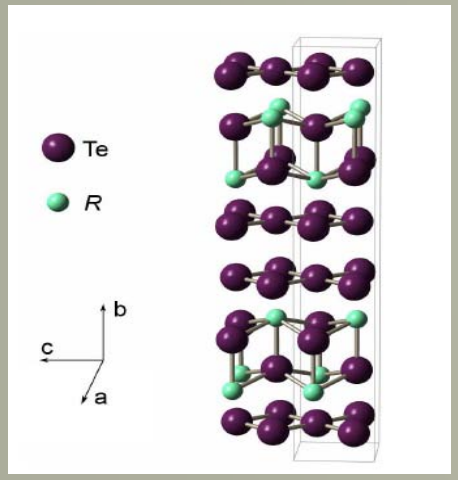
1. Family of compounds *R*Te_3 (*R*=Y, La, Ce, Nd, Sm, Gd, Tb, Ho, Dy, Er, Tm). Properties.
2. Motivation
3. CDW sliding in $ErTe_3$.
4. Nonstationary effects in $ErTe_3$. New motivation.
5. Hall effect in $ErTe_3$, HoTe3 and TbTe3
6. Conclusions

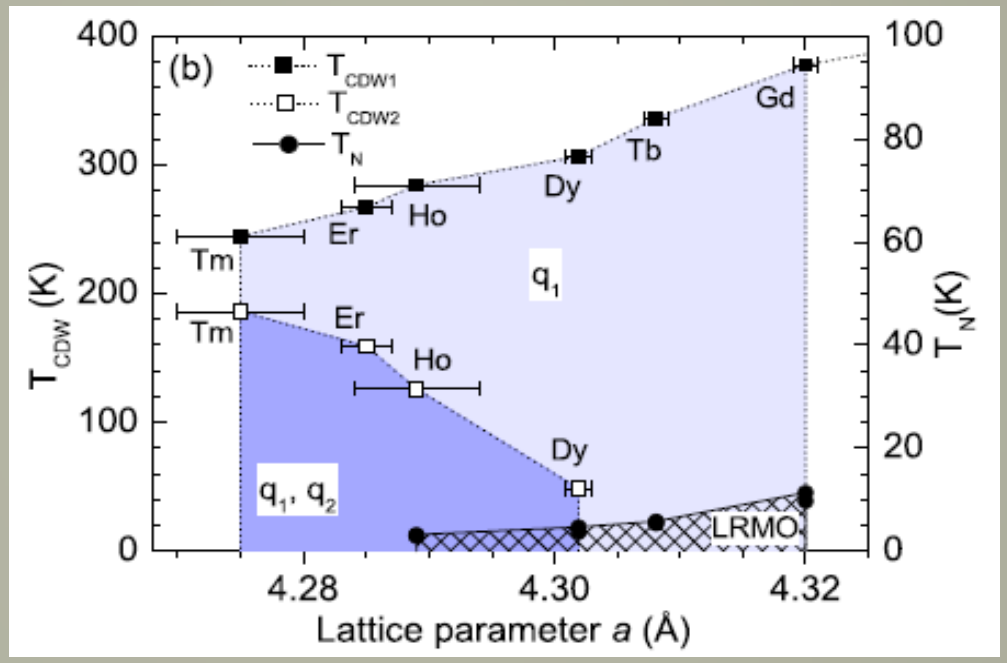
RTe_3

(*R*=Y, La, Ce, Nd, Sm, Gd, Tb, Ho, Dy, Er, Tm)

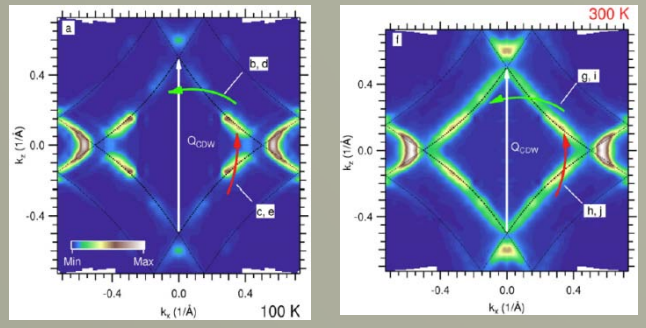
Layered quasi-two dimensional compounds

Crystal structure
– weak orthorhombic





Fermi surface for $TbTe_3$.

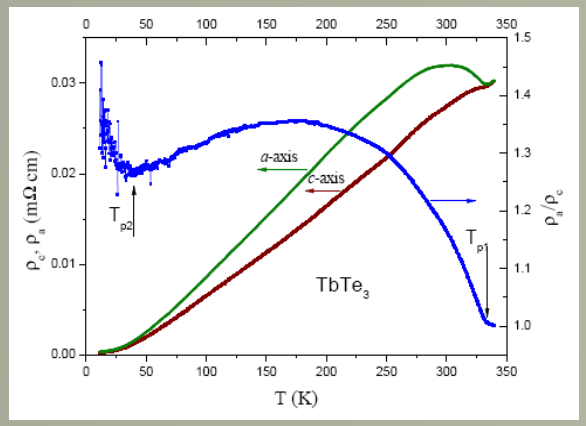


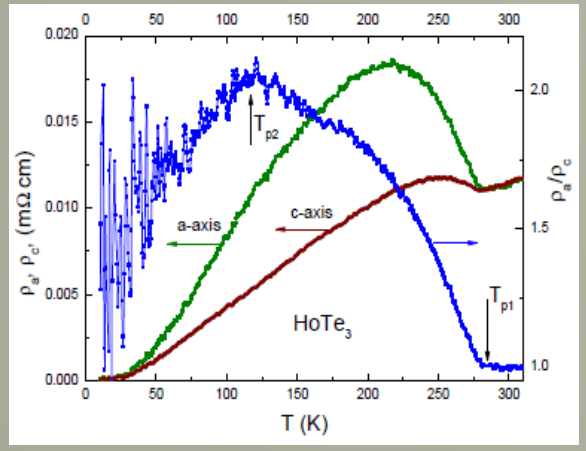
(F. Schmitt et al., New Journal of Physics 13, 063022, 2011)

Incommensurate CDW below the temperature T_{CDW1} through the whole R series with a wave vector Q_{CDW1} =(0,*0*, ~2/7*c). For the heavier R (Dy, Ho, Er, Tm) atoms *a* second CDW occurs at low temperature T_{CDW2} with the wave vector Q_{CDW2} = (~2/7*a**,0,0) *perpendicular* to Q_{CDW1}**

RTe_3 (CDW properties)

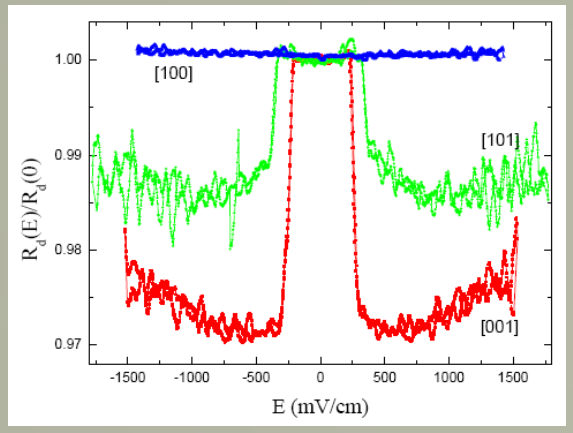
Resistive effect of CDW. Inverted anisotropy

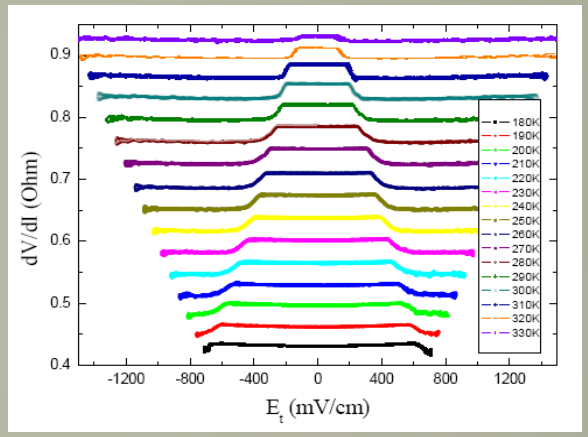


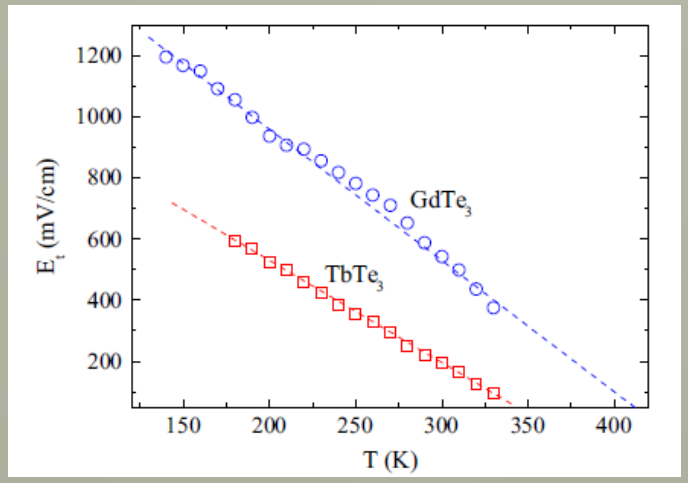


(PRL, 112, 036601 (2014))

CDW sliding





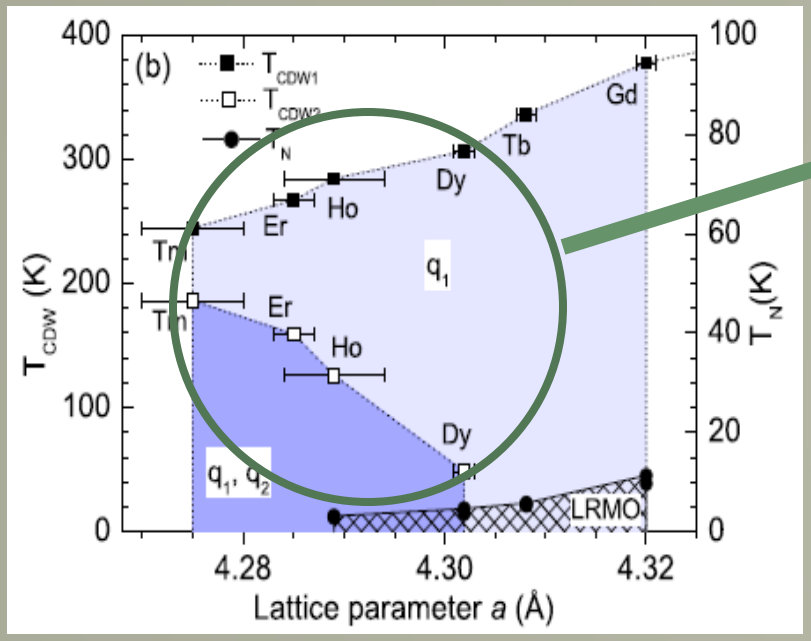


Linear Dependency $E_t(T)$

$$E(T) = E(0)(1 - \frac{T}{T_0})$$

$$T_0 \approx 1.08 T_{CDW}$$

(SSC. 188, 67 (2014))



Compounds with bidirectional CDWs

"Both CDWs exist within the same Te plane, thus both CDWs modulate the positions of the same Te atoms." (?)
"…. each CDW appears unidirectional and completely decoupled." (?)
(R. G. Moore, et al., PRB 81, 073102 2010)

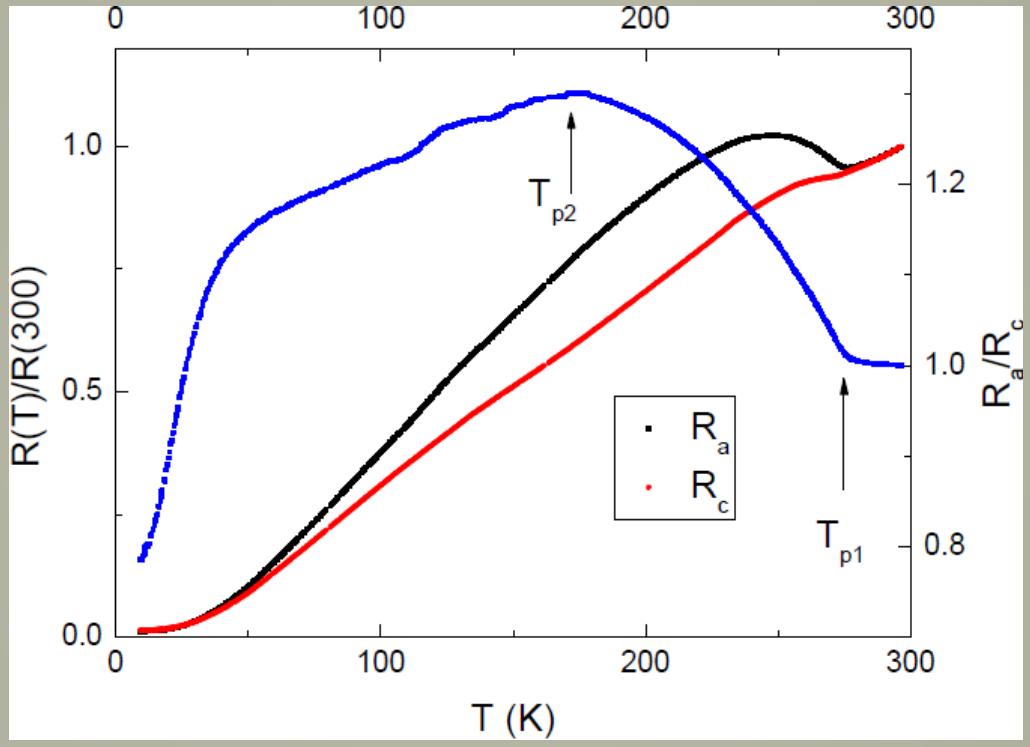
Motivation

1. **Is the collective sliding possible for second CDW?**
2. **What is the temperature dependency of E_t for CDW1 across the second Peierls transition? Or, are these CDWs completely decoupled?**

Experiment

$ErTe_3$

T_{CDW1}=270 K
T_{CDW2}=165 K

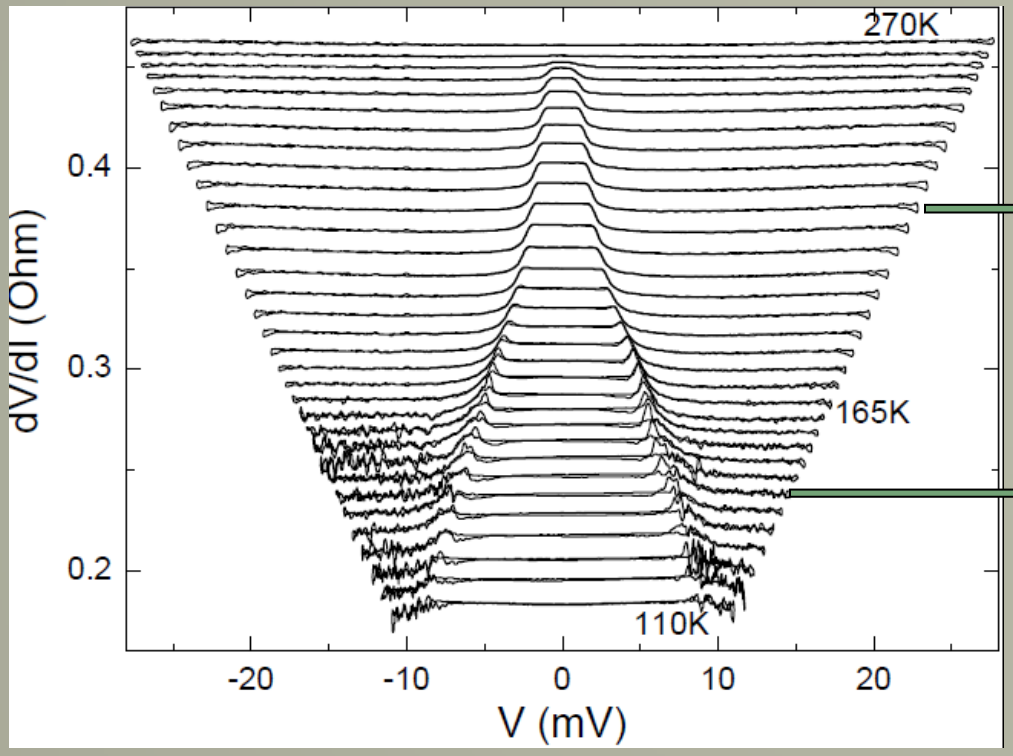


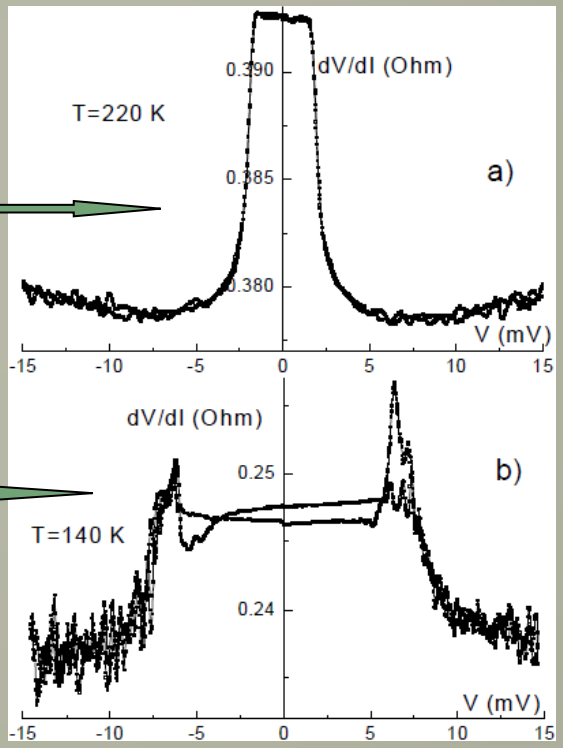
From untwinned single crystals with a thickness typically 0.2–2.0μm, the stripes with a length of a few millimeter and a width 50–80 μm in well defined orientation, namely [100] and [001] have been cuted.

PRB, 93, 235141 (2016)

CDW sliding in $ErTe_3$ (CDW1)

Contribution of CDW: ΔR/R~3% - low CDW velocity (?)



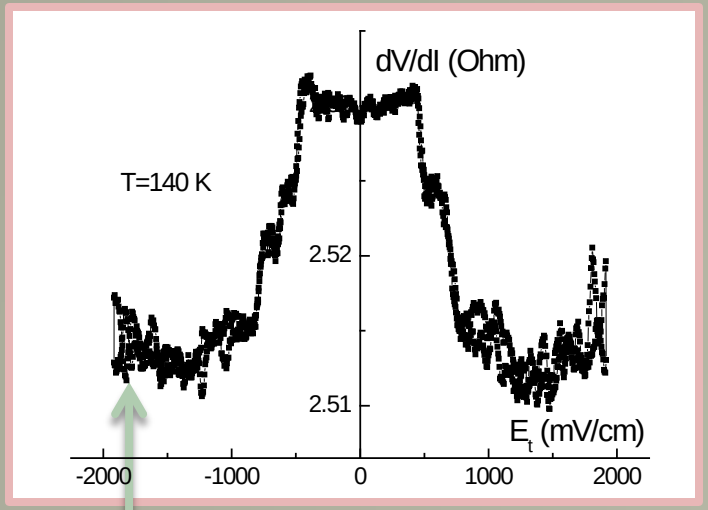


The temperature evolution of differential IV curves in the temperature range 270–110 K

PRB, 93, 235141 (2016)

The shape of IV characteristics change qualitatively for temperatures above and below T_{CDW2}

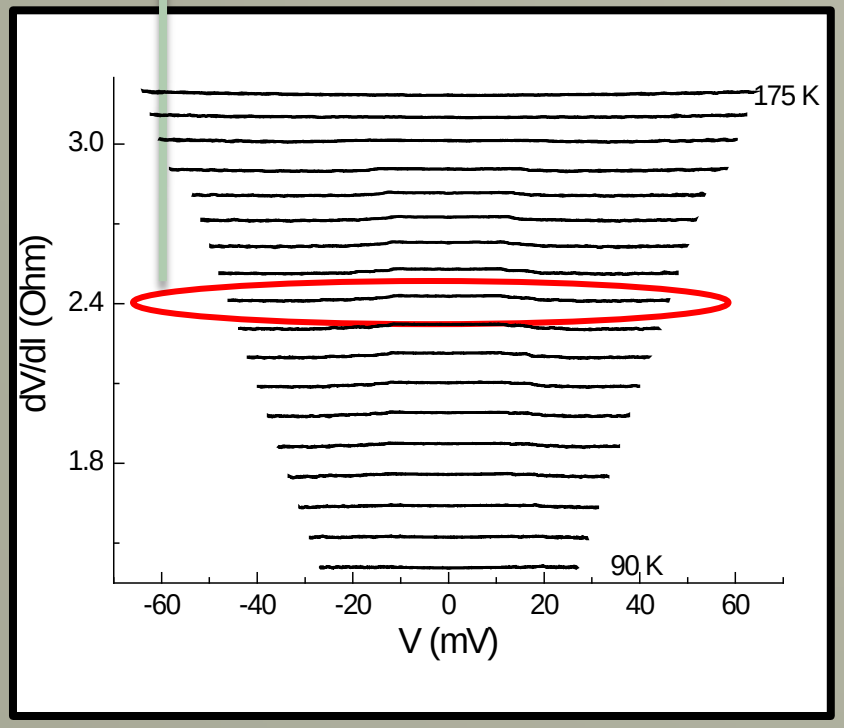
CDW sliding in $ErTe_3$ (CDW2)

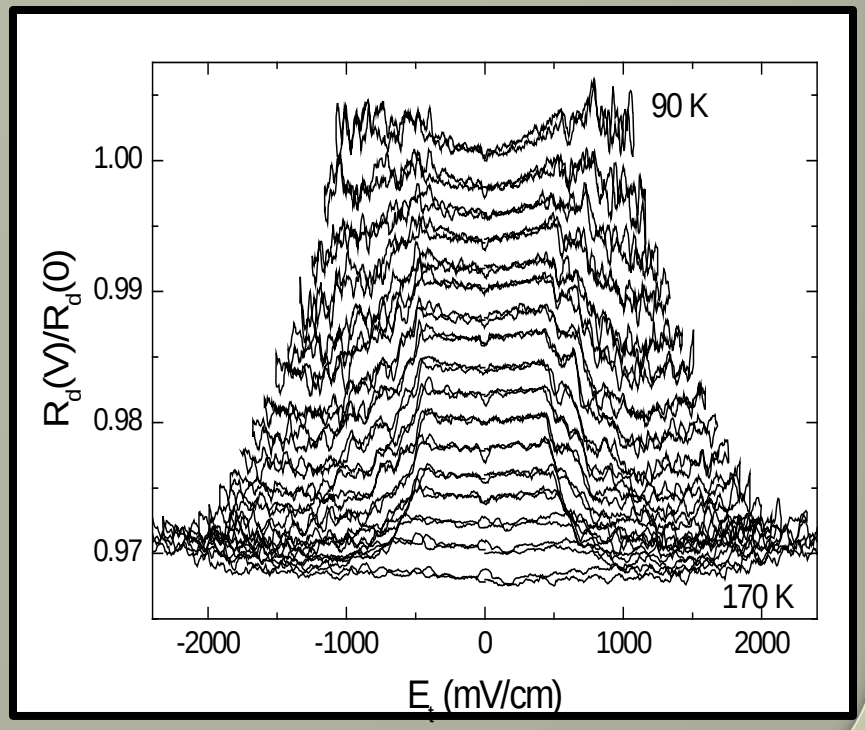


Contribution of CDW:

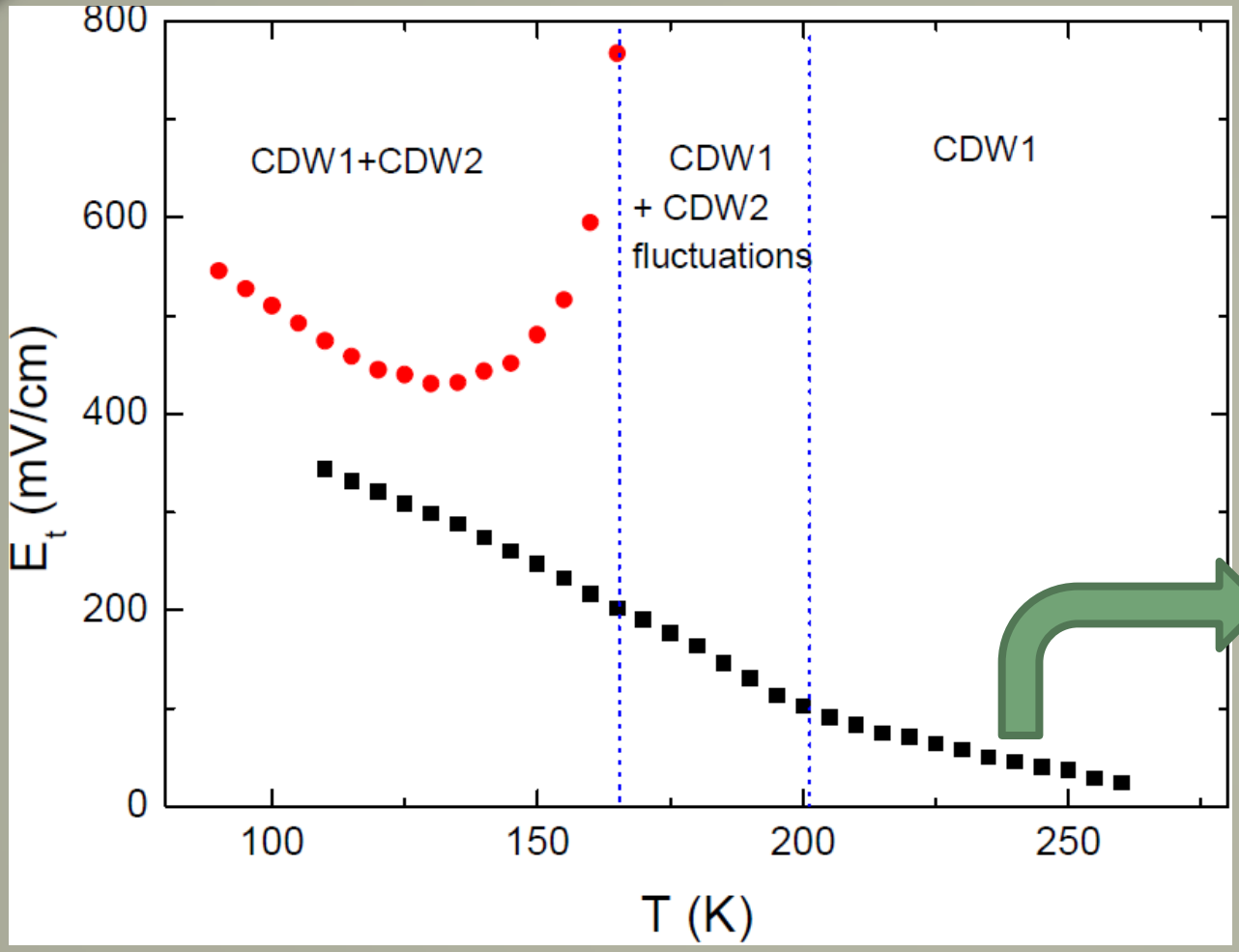
$\Delta R/R \sim 0.3\%$

- <u>very</u> low CDW velocity (?)





PRB, 93, 235141 (2016)



High T region – $E_t(T)$ – linear, analogously to $E_t(T)$ in unidirectional CDW compounds ($TbTe_3$, $GdTe_3$)

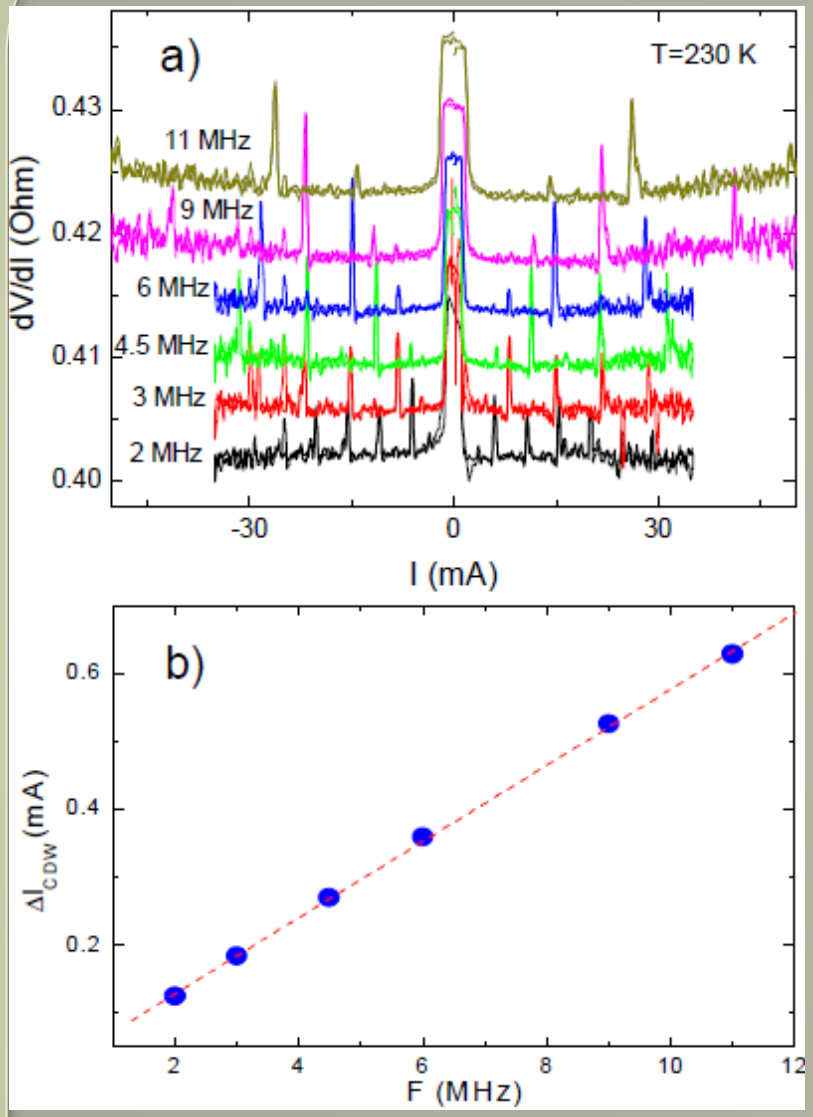
$$E(T) = E(0)(1 - \frac{T}{T_0})$$

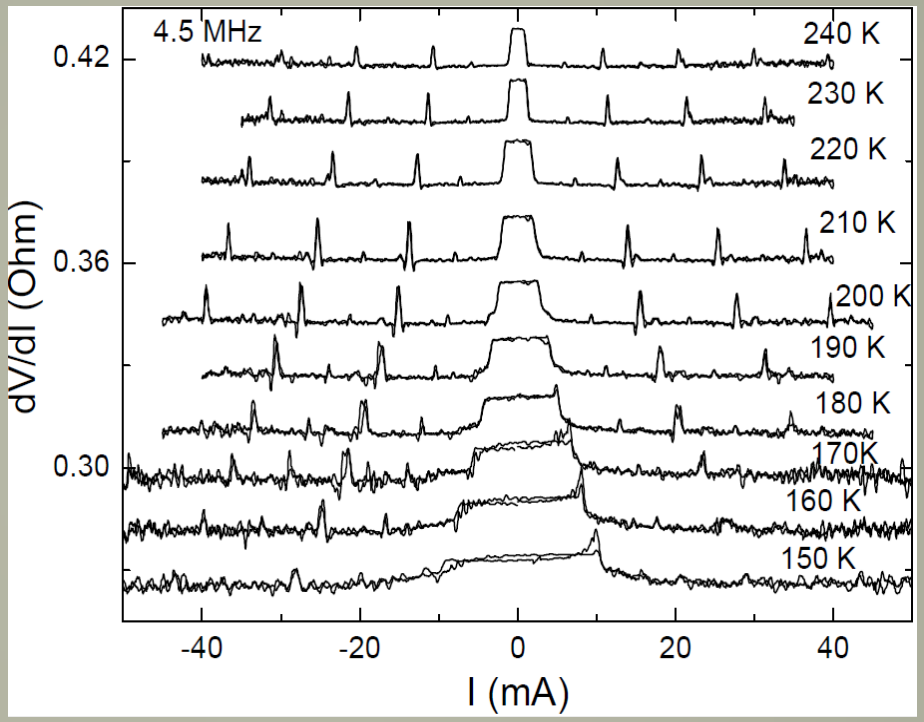
E(0) = 235 mV/cm
$T_0 = 1.07T_{CDW1}$
in accordance with (SSC. 188, 67 (2014))

Below ~200 K visual deviation from linear law.
Below T_{CDW2} – near linear dependence again.

Conclusion 1: CDW1 and CDW2 are interacting

Nonstationary effects (CDW1)





1D – for one chain- $\frac{j_c}{f_0} = 2e$

$\Delta I_{CDW}/f_0 = 6.1 \times 10^{11}$ A/Hz $S = 2.1 \times 10^{-6}$ cm^2

Number of chains per cross-section 1.90×10^8

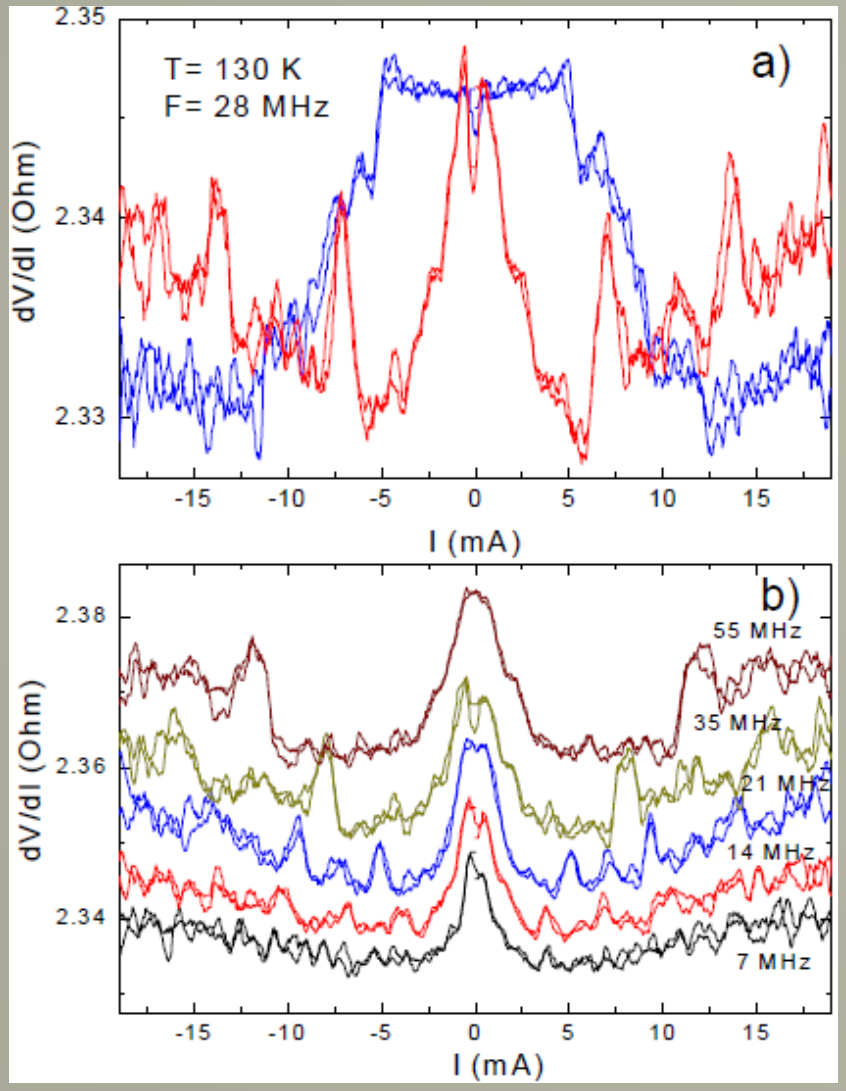
Number of unit-cells per cross-section- 1.96×10^8

$ErTe_3$

$b^* = 25.02$ Å

$a^* = 4.29$ Å

Nonstationary effects (CDW2)



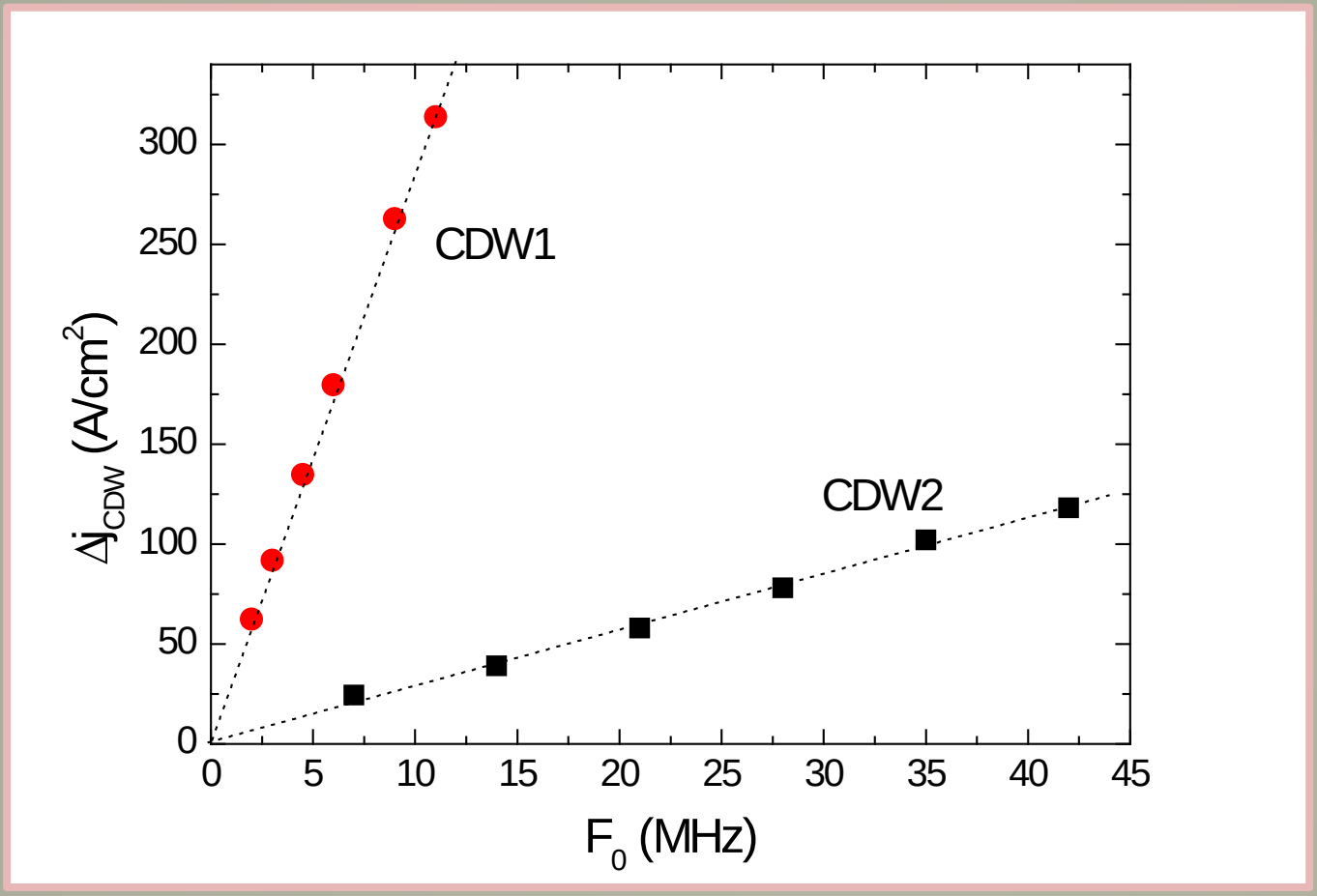
$\Delta I_{CDW}/F_0=1.7\times10^{-12}$ A/Hz

$N_{chain}=0.53\times10^{7}$

$S=0.25\times10^{-6}$ cm^2

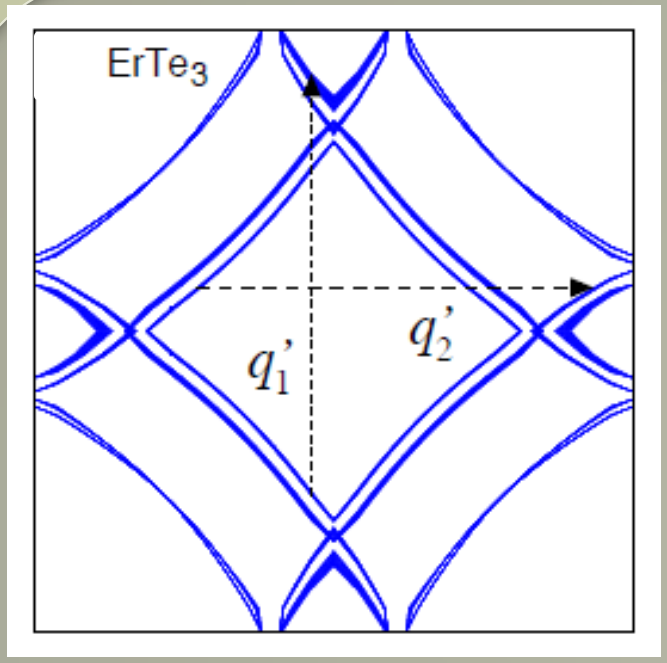
$S_{unit\ cell}=1.07\times10^{-14}$ cm^2

$N_{unit\ cell}=2.3\times10^{7}$



Different number of carriers condensed to CDW1 and CDW2,
Or, additional pinning effects,
Or, ...

???



"The onset of a single CDW suppresses N_{EF} to 77% of the unmodulated value while the second CDW further suppresses N_{EF} to 74%."
[R. G. Moore, et al., PRB 81, 073102 2010]

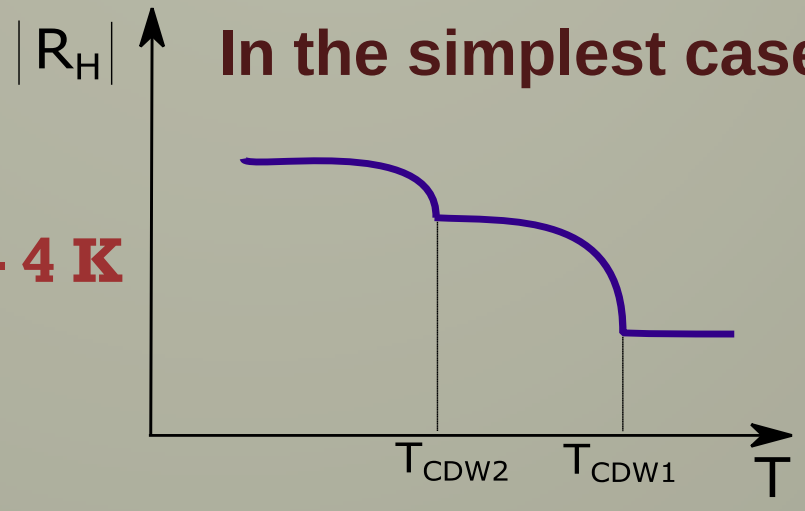
Hall effect. What can one expect?

MEASUREMENTS

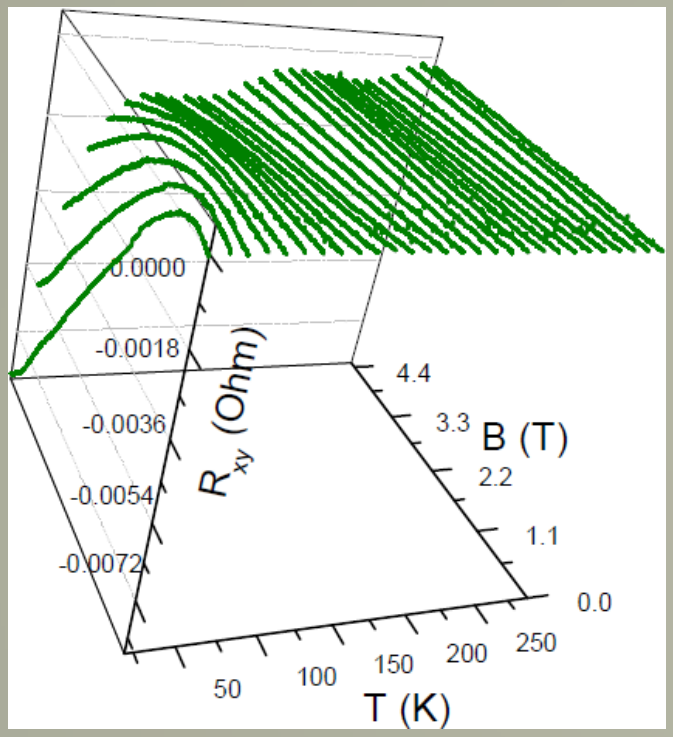
van der Pauw method

$R_{xy}(\pm B)$ in the range 300 – 4 K
at fixed T
with ΔT=10 K

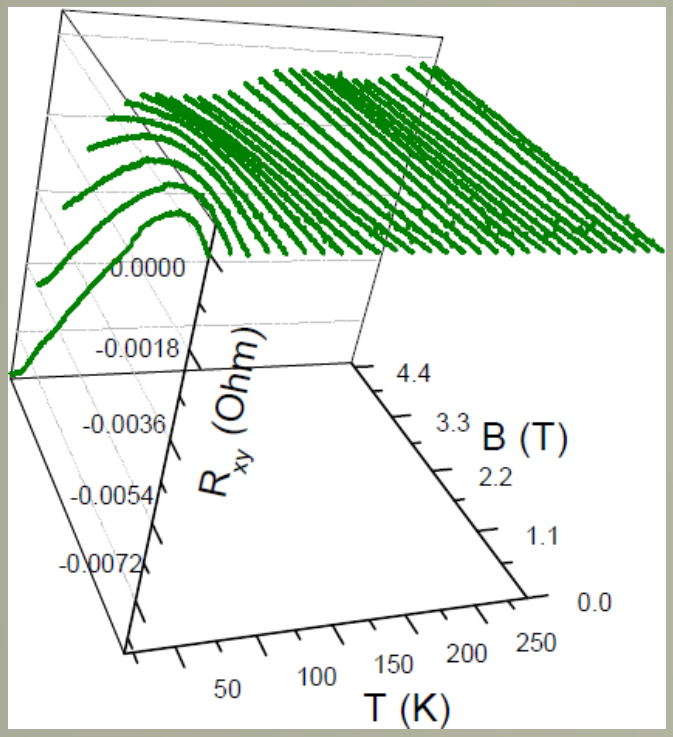
In the simplest case

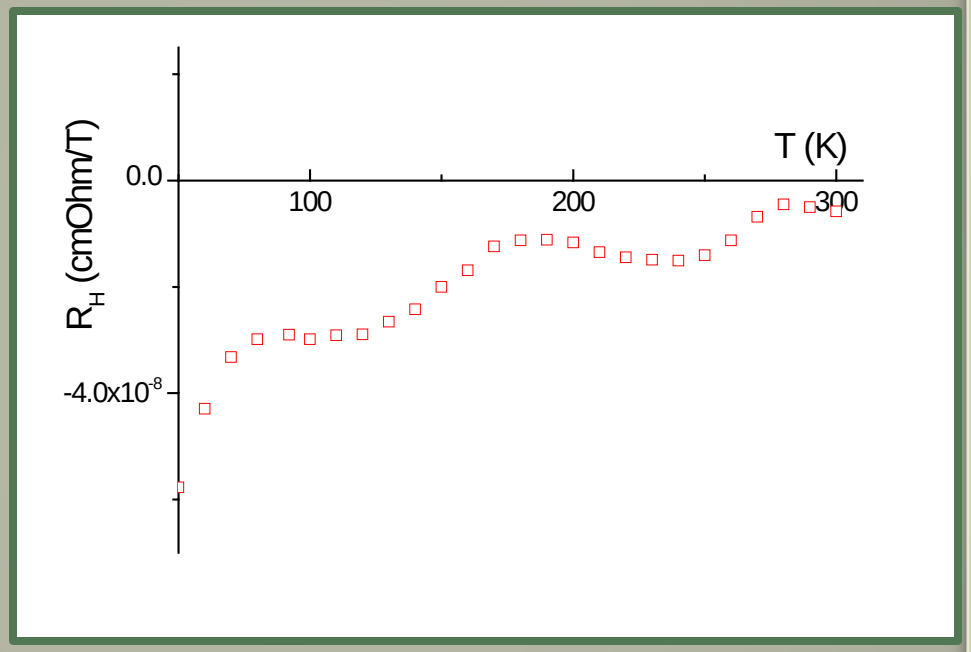


Hall effect in $ErTe_3$

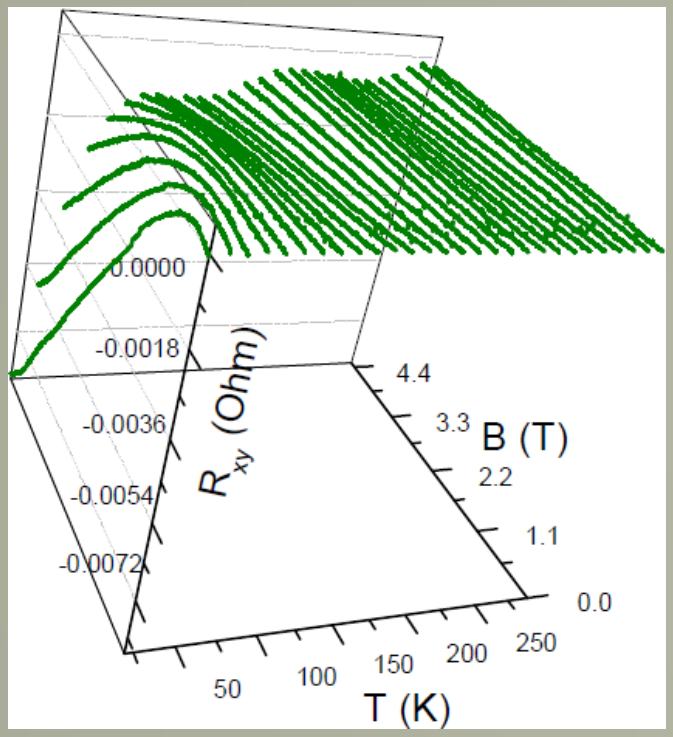


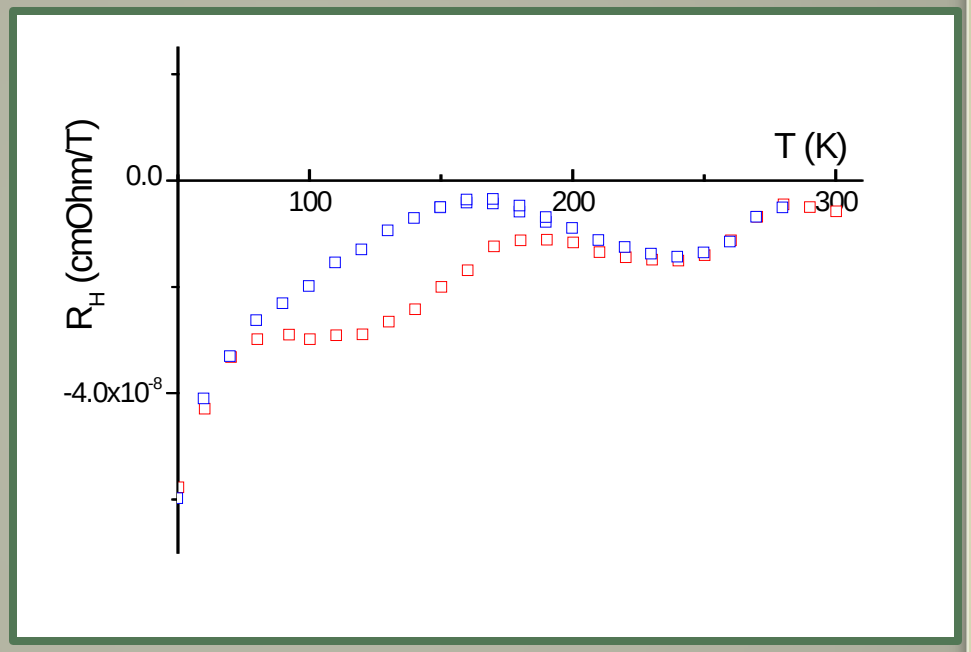
Hall effect in $ErTe_3$



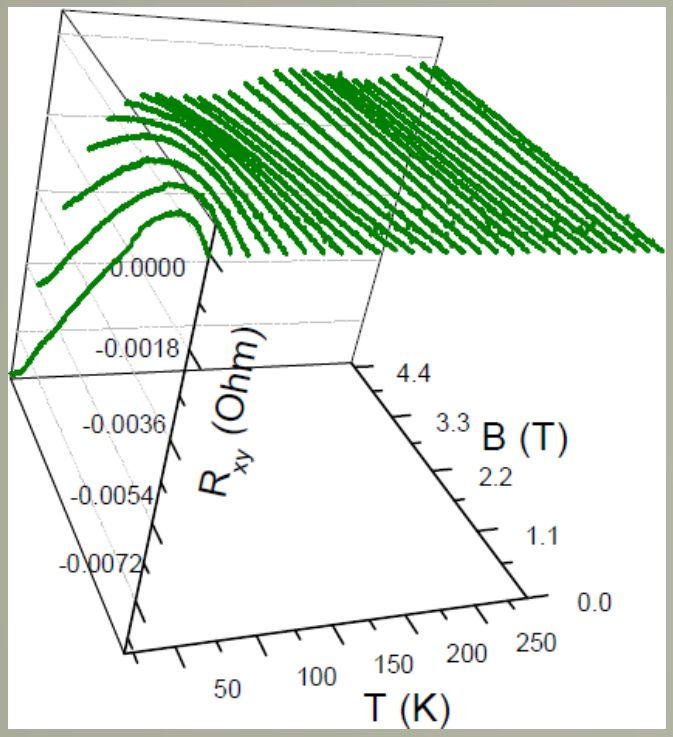


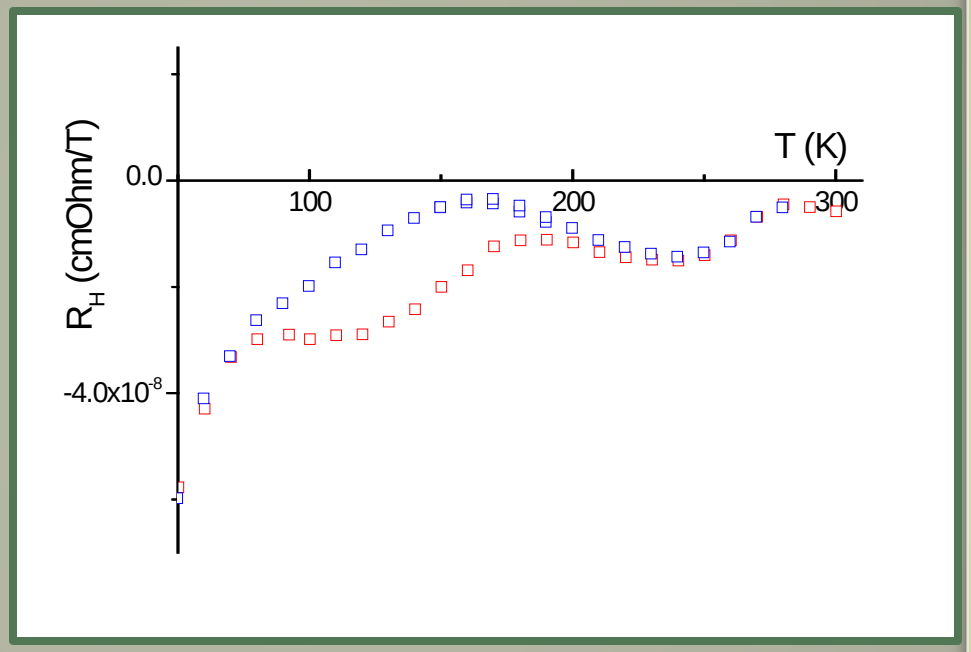
Hall effect in $ErTe_3$

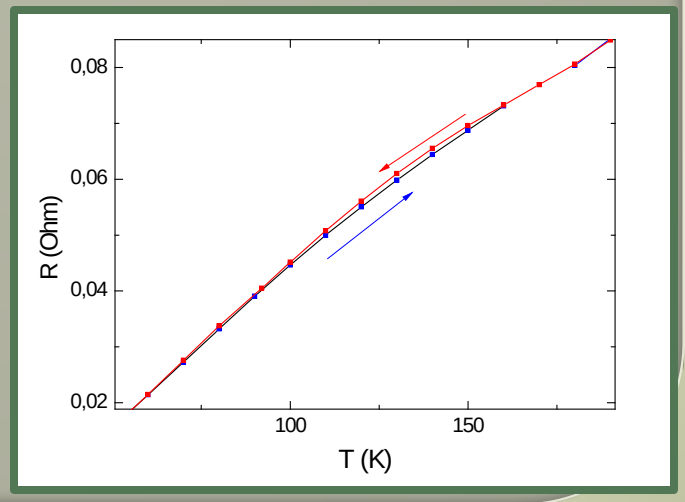




Hall effect in $ErTe_3$



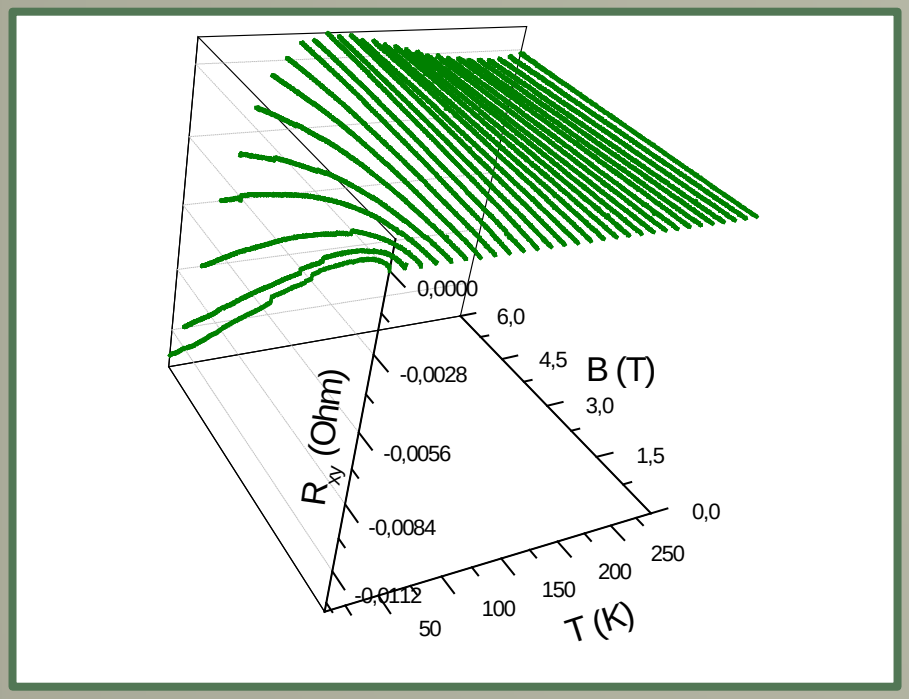




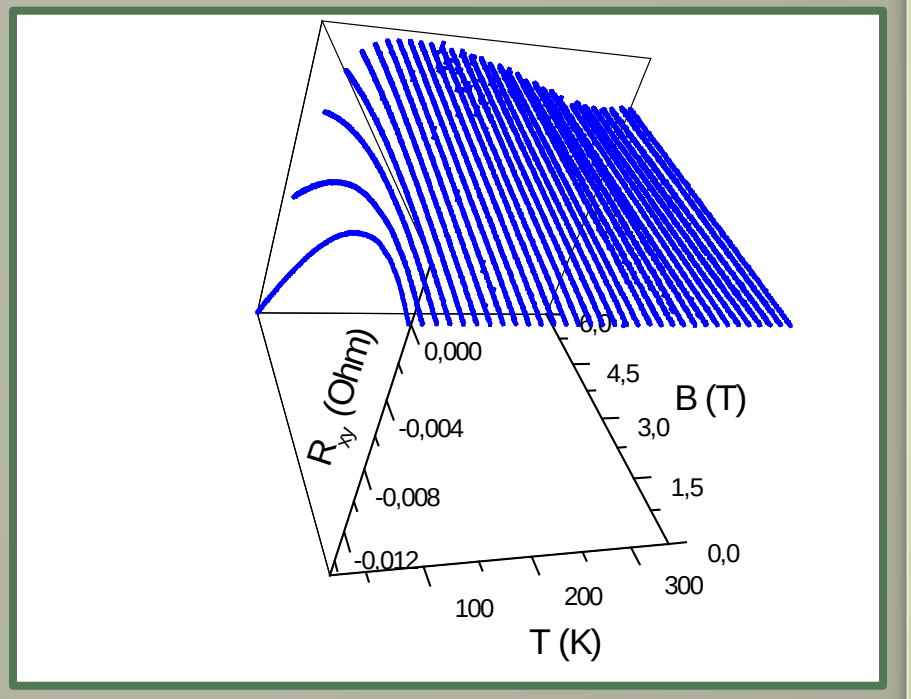
Gigantic hysteresis of Hall constant in the temperature region of CDW2 formation (?) + <u>no hysteresis in R(T)</u>

Hall effect in:

bidirectional
$HoTe_3$ (T_1=287K, T_2=110K)

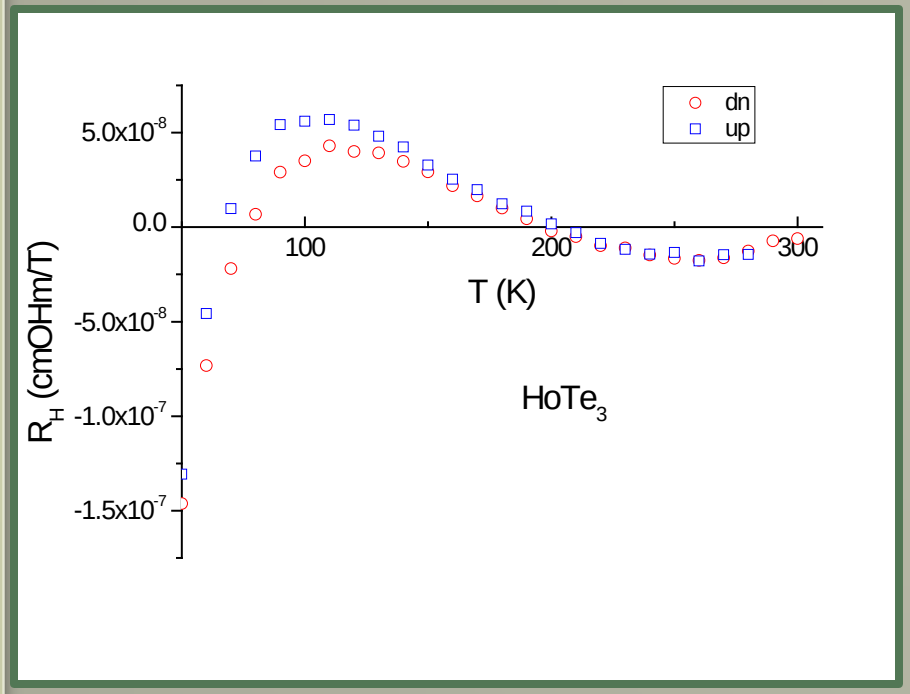


unidirectional
$TbTe_3$ (T_1=336K)

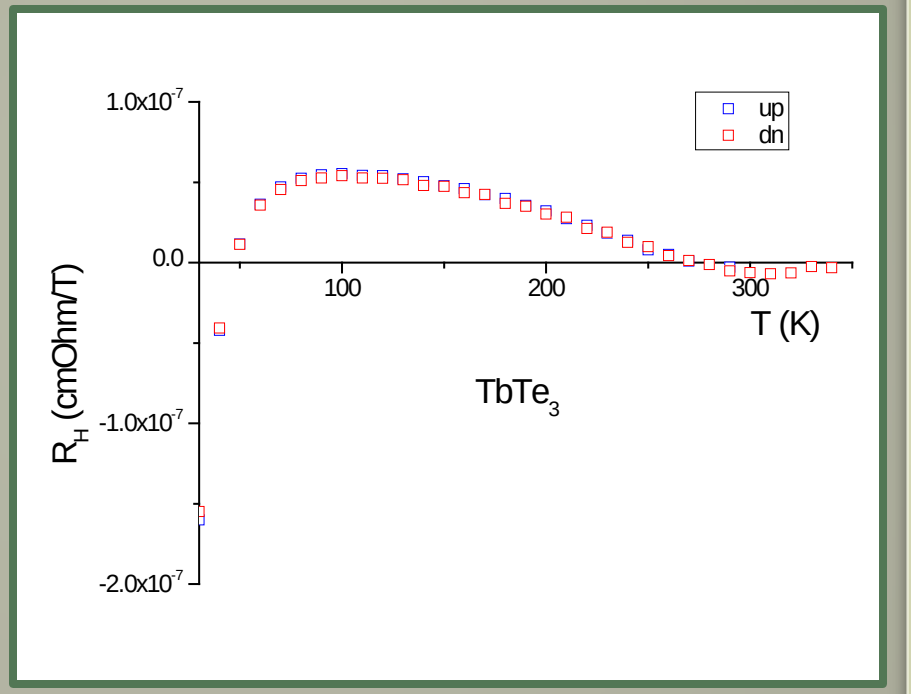


Hall effect in:

bidirectional
$HoTe_3$ (T_1=287K, T_2=110K)



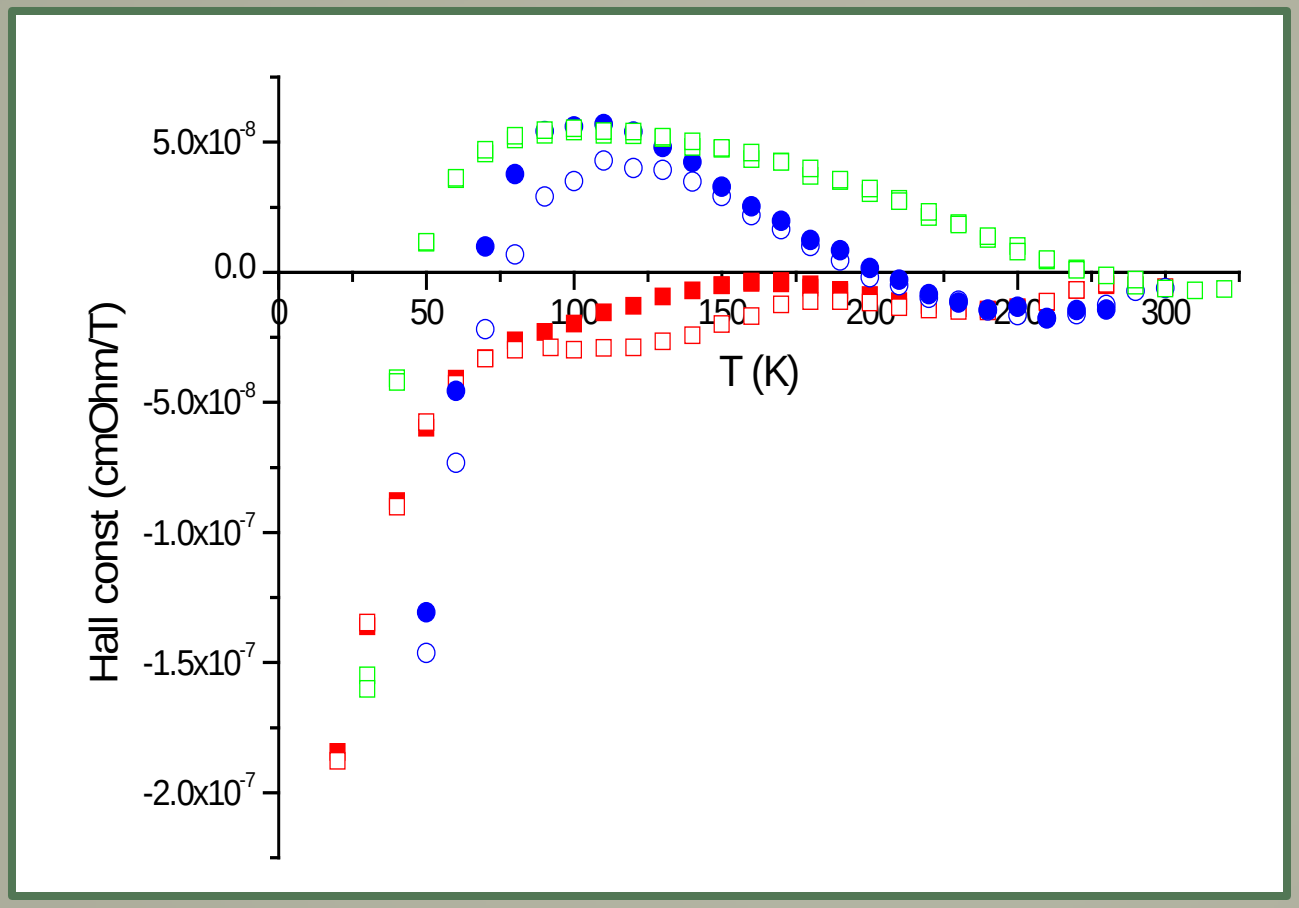
unidirectional
$TbTe_3$ (T_1=336K)



Hysteresis ⟹ in the region of CDW2 formation.
Hysteresis of Q-vector ???

New question:
$HoTe_3$ и $TbTe_3$ ⟹ two inversion points.

All together



Compounds RTe_3 ⟹ (near) compensated metals

Conclusions:

1. Sliding of low-T CDW is possible in the Q-vector direction.
2. Bidirectional CDWs are interacting.
3. Gigantic Hall effect hysteresis observed in the temperature range corresponding to CDW2 formation that may be indication of hysteresis of the CDW wave vector.

Thank you very much for your attention