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SMR 1232 - 26

XII WORKSHOP ON
STRONGLY CORRELATED ELECTRON SYSTEMS

17 - 28 July 2000

HALL MEASUREMENTS ON 1D CONDUCTORS

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These are preliminary lecture notes, intended only for distribution to participants.

Hall-effect in Q-1D organic conductors

Dimensional crossover, electronic confinement and charge localization

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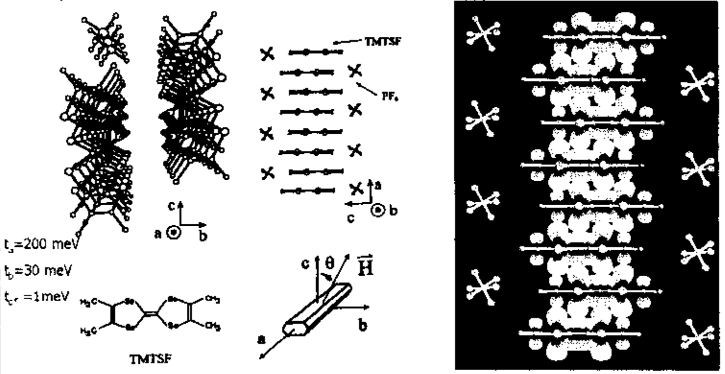
Introduction

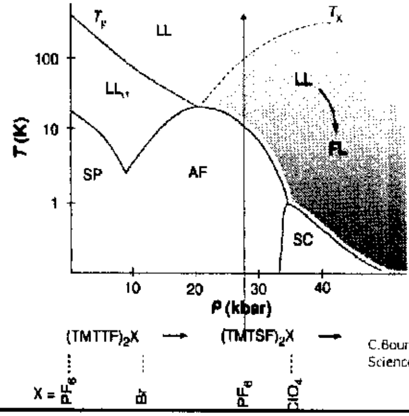
- Structure and phase diagram of the Bechgaard salts
- Fermi liquid – Luttinger liquid
- Optical experiments–spectral weight of the Drude mode

Crystal Structure of the Bechgaard salts $(TMTSF)_2PF_6$



σ_a=30000Ω^{-1}cm^{-1}, σ_b=300Ω^{-1}cm^{-1},

Phase diagram of the Bechgaard salts



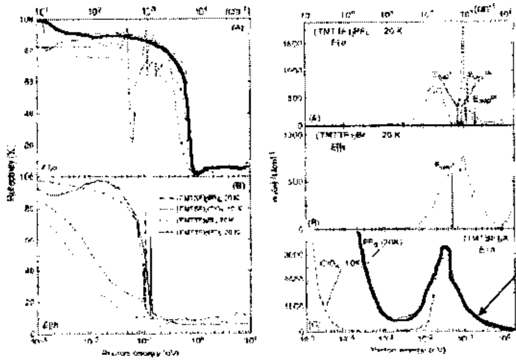
C.Bourbonnais and D. Jérome, Science 281,1155 (1998)

Fermi liquid – Luttinger Liquid

- C. Bourbonnais:
- G.D. Clarke, S.P. Strong

	$T > t_\perp$	∥ coherent	⊥ incoherent
Observability of LL exponents:		$l_a > a$	$l_b < b$
	$T \ll t_\parallel$	« confined coherence »	

Optical measurements



Drude weight:

1% of $\int\sigma(\omega)d\omega = \pi ne^2/2m$

$\tau \approx 10^{-11}$ s

$l \geq 10$ µm

High frequency mode: $\sigma(\omega) \sim \omega^{-1/3}$

Vescoli et al., Science 281, 1181 (1998)

Hall effect in Q-1D organics

- Previous Hall measurements
- Hall geometries
- $(TMTSF)_2PF_6$ - Mihály et al.
  - Moser et al.

Previous Hall measurements

HMTSF-TCNQ, TTF-TCNQ

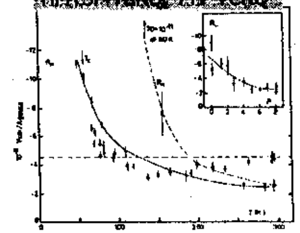


FIG. 3. — Temperature dependence of R_H for TTF-TCNQ compared with that of HMTSF-TCNQ. TTF-TCNQ at ambient pressure, open triangles results for two cooling cycles on sample 7, open circles, sample 5. Solid circles, sample 3, at 6 kbars. Crosses HMTSF-TCNQ at atmospheric pressure. *Inset*. Pressure dependence of R_H at room temperature for TTF-TCNQ samples 3 (solid circles) and 4 (open circles).

J.R. Cooper et al, J. Physique, 37, 349 (1977)

J.R. Cooper et al, J. Physique, 38, 1097(1978)

TMTSF-DMTCNQ

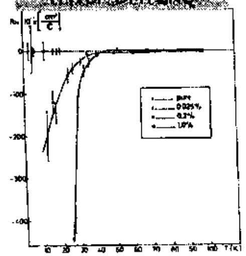
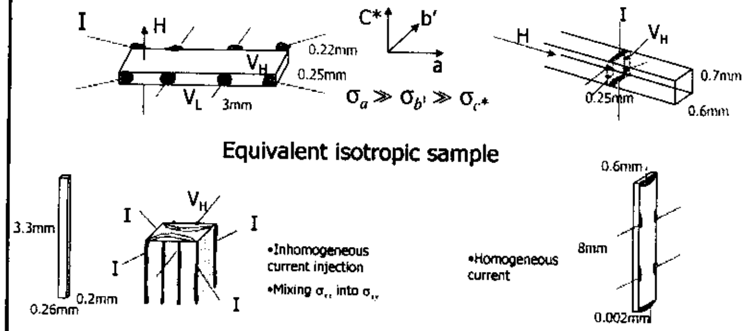


Fig. 2. — Low-temperature part of the Hall coefficient of TMTSF-DMTCNQ for pure and irradiated samples.

L. Forró, J. Physique, 43, 977 (1982)

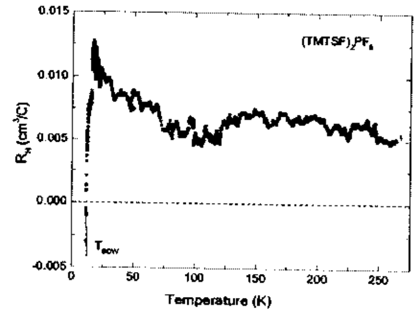
Hall geometries



Moser et al., PRL, 84, 2670(2000).

G. Mihály et al., PRL, 84, 2670(2000).

Hall coefficient in the normal metallic phase (I || c^*)



In a naive Drude-picture:

R_H = 1/ne= 4×10^{-3} cm^3/C $\leftrightarrow$ n = 1.2×10^{21} cm^{-3}

Drude weight:

1% of $\int\sigma(\omega)d\omega = \pi ne^2/2m$

→A factor of 100 enhancement of R_H is expected!

Zotos et al (PRL 85, 377 (2000)):

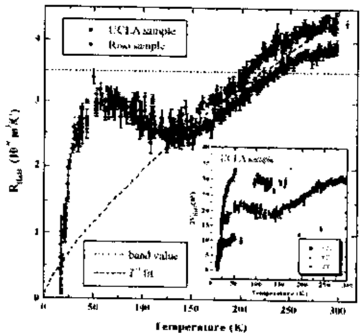
$R_H = -d\ln(D)/dn$

If $D = cn$ than for any type of many particle interactions:

R_H = -1/ne

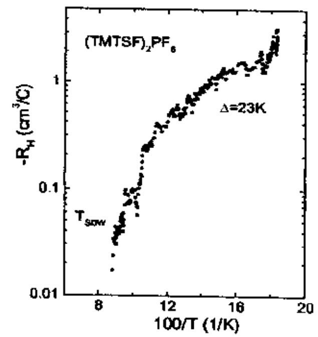
G. Mihály et al., PRL, 84, 2670(2000).

Hall coefficient in (I || a)



Moser et al., PRL, 84, 2670(2000).

Hall coefficient in the SDW phase

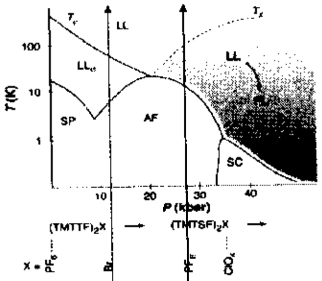


G. Mihály et al., PRL, 84, 2670(2000).

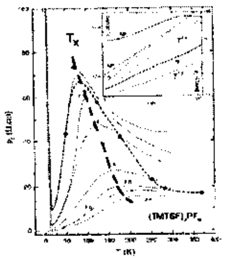
Conduction along various directions

- Comparison of $(TMTSF)_2PF_6$ and pressurized $(TMTTF)_2Br$
- Conduction anisotropy in $(TMTSF)_2PF_6$
- a,b and c* direction conductivity of TMTTF family
- Pressure induced delocalization in $(TMTTF)_2Br$

Motivation

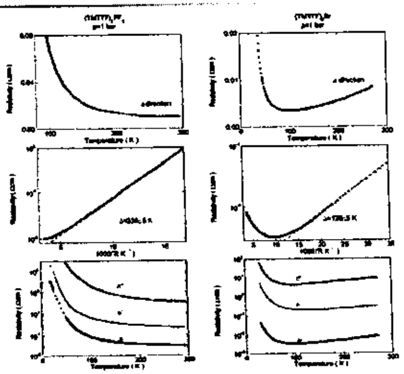


C.Bourbonnais and D. Jérome, Science 281,1155 (1998)



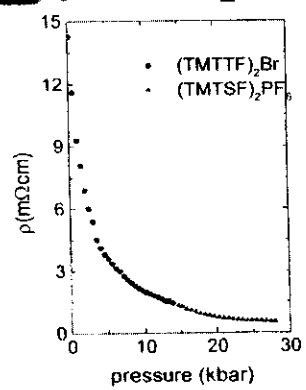
Moser et al., Euro. Phys. J, B1, 39 (1998)

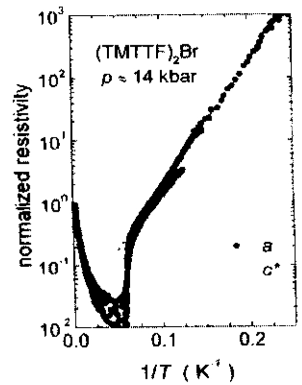
$(TMTTF)_2X$, $X=PF_6$, Br



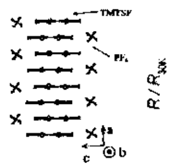
$T_{min} \approx \Delta_\rho$

$(TMTTF)_2Br$ under pressure





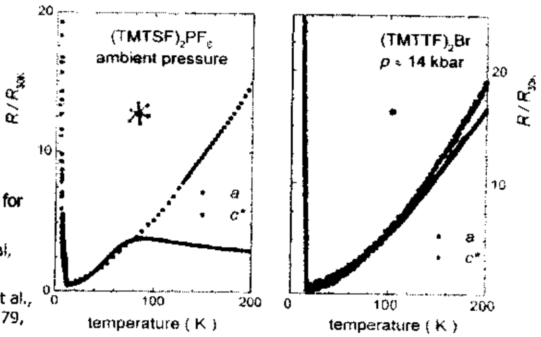
$(TMTSF)_2 PF_6 \leftrightarrow (TMTTF)_2Br$



PF_6 anion rotation for T>70 K

[19]F NMR: Brierty et al, SSC 43, 679 (1982)

Proton NMR: Scott et al., Mol.Cryst.Liq.Cryst., 79, 41 (1981).



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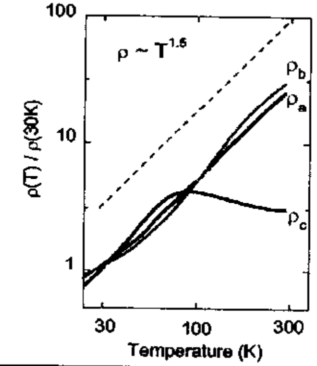
$(TMTSF)_2 PF_6$:anisotropy



$\rho_a(T) \sim \rho_b(T) \sim T^{1.5}$

For T>50K, $l_b < b$

2D→1D crossover

Interchain hopping probability:

$\tau_b(T)^{-1} = \tau_a(T)^{-1}\, t_b^2/\hbar^2$

M. Weger, J. Physique 39, 1456 (1978).

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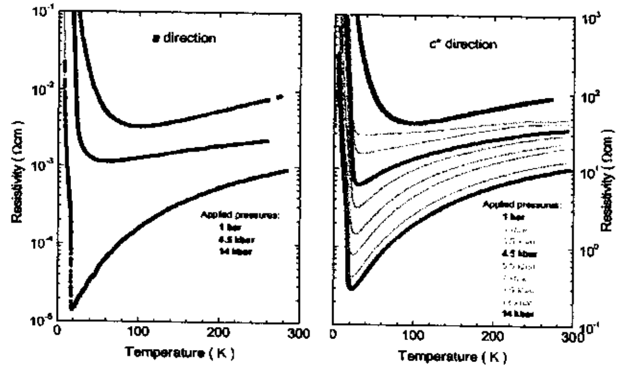
$(TMTTF)_2Br$ at various pressures



Zámborszky et al. to be published

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Conclusions

- Hall effect

-« Normal magnitude » of $R_H = -1/ne$ (might be consistent with the small Drude-weight , see Zotos et al.

- Anisotropic conduction

- No FL-LL phase boundary at T_x (derived from c*-axis resistivity of $(TMTSF)_2PF_6$).
- b'-axis transport becomes incoherent for T>50K: 2D →1D crossover, but the a-b' anisotropy does not change.
- Continuous delocalization of the electrons along the chains in $(TMTTF)_2Br$ with pressure.

- Phase diagram

- No strong evidences for LL state in $(TMTSF)_2PF_6$. Smooth crossovers: localized states→1D Fermi liquid→2D Fermi liquid.
- Incoherent-coherent regions cannot be separated by phase boundaries.

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