From 1D to D
(and beyond !)

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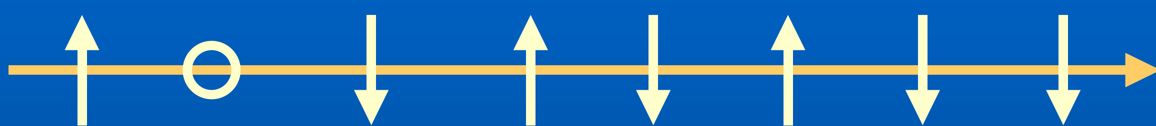
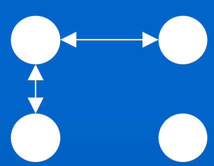
Question



- 1 chain : Luttinger Liquid

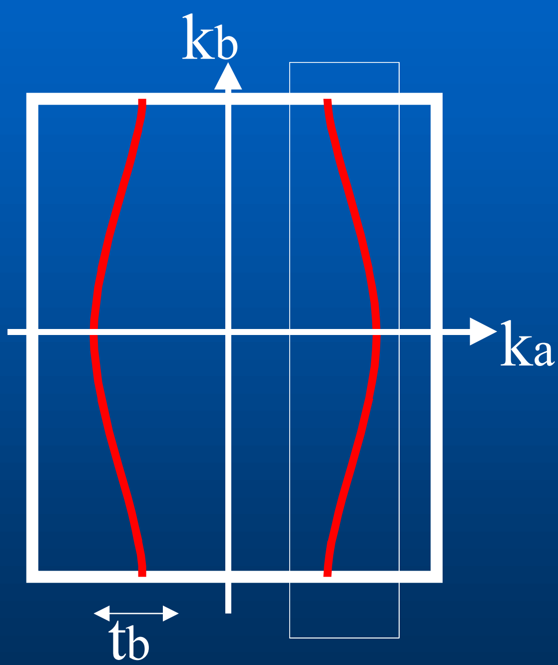
- Coupled chain : Fermi liquid ????

How to go from 1d to 3d



$$t_a > t_b > t_c$$

$$3000K, 300K, 20K$$



- High Energy (T,ω): 1D
- Low Energy (T,ω) : 2D,3D

Dimensional crossover

How is it modified by interactions ? T* ?

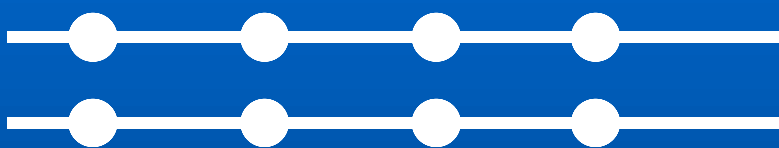
- Renormalization arguments
  (Bourbonnais, Brazovskii+Yakovenko, Schulz)

$$E^* \sim t_\perp (t_\perp / t)^{\alpha/(1-\alpha)}$$

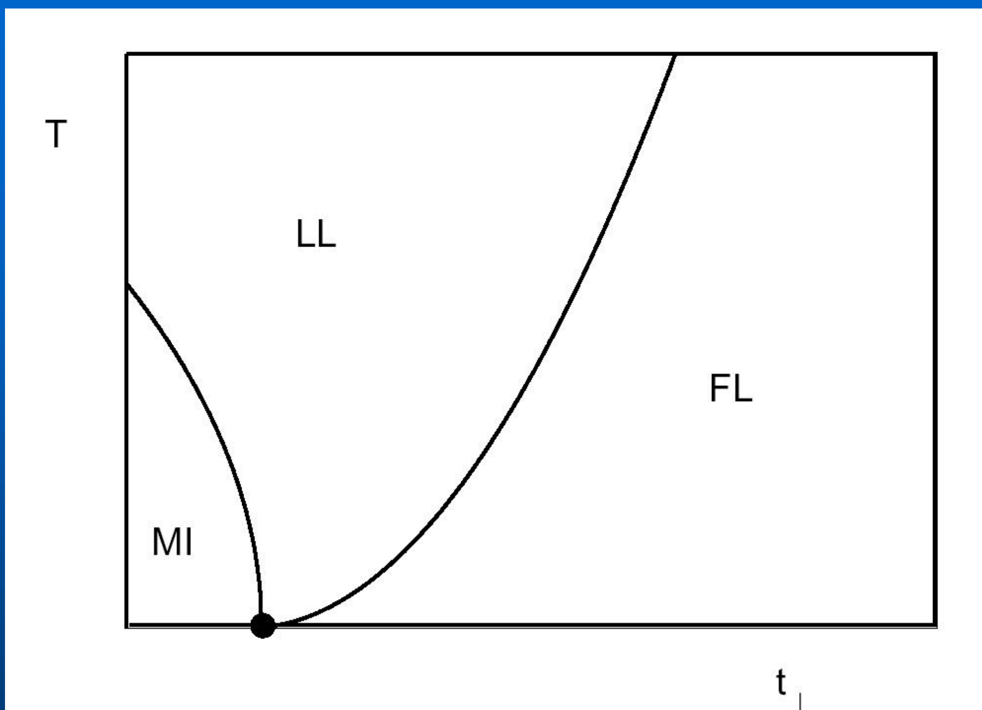
$$\alpha = \frac{1}{4}(K_\rho + 1/K_\rho) - \frac{1}{2}$$

Strong reduction of crossover temperature. But hopping still relevant !

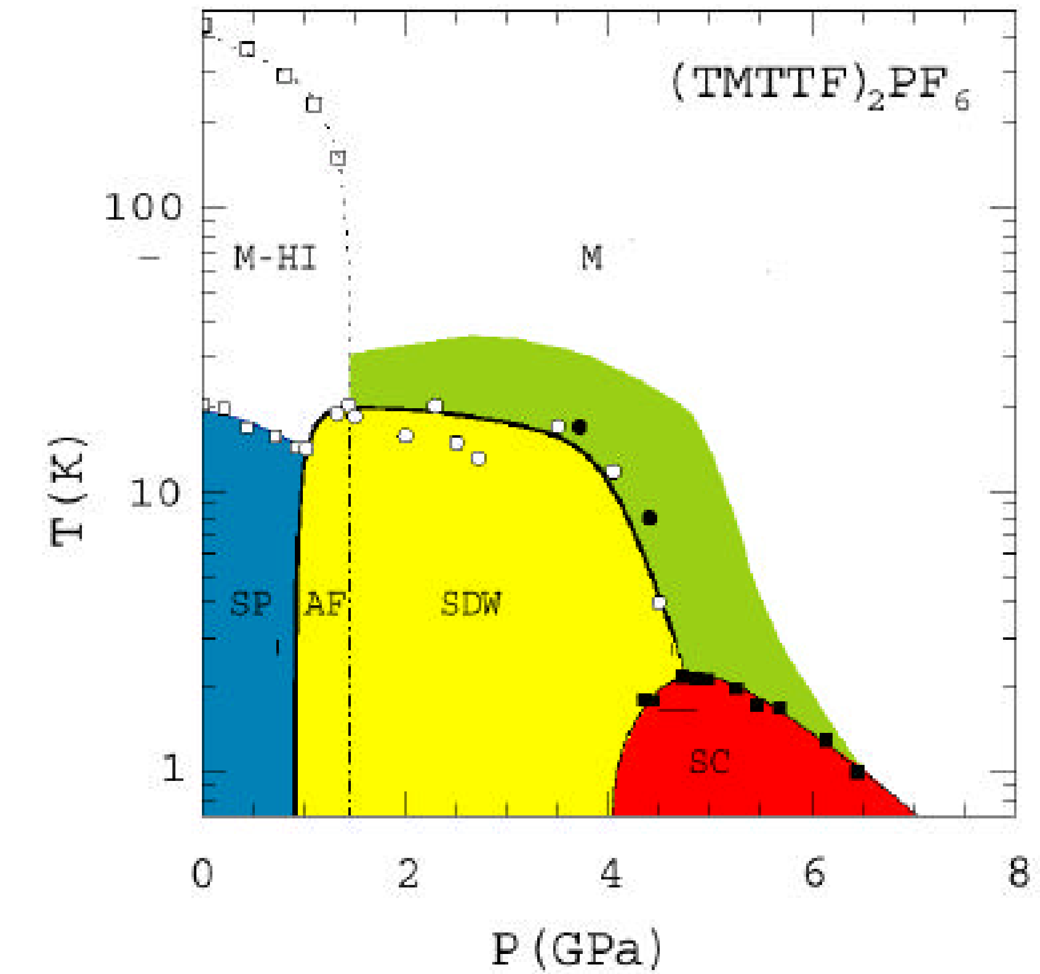
Mott insulators: confinement



Competition Mott insulator/Interchain hopping



- How to study ?
- Difficult (RG, RPA, etc.)

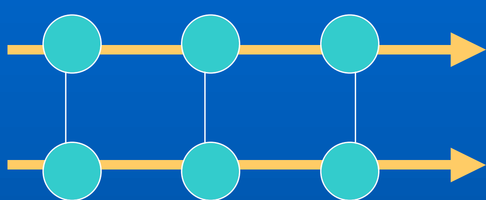


After D. Jérome

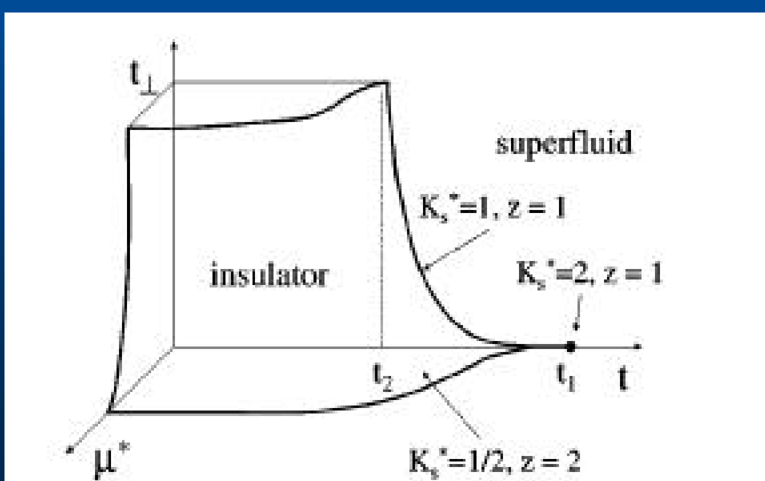
Ladders

- 2 one dimensional chains
- « Simple » analytical solution
- NO deconfinement for fermionic ladders : always insulating
- Interesting phases : Orbital antiferromagnet

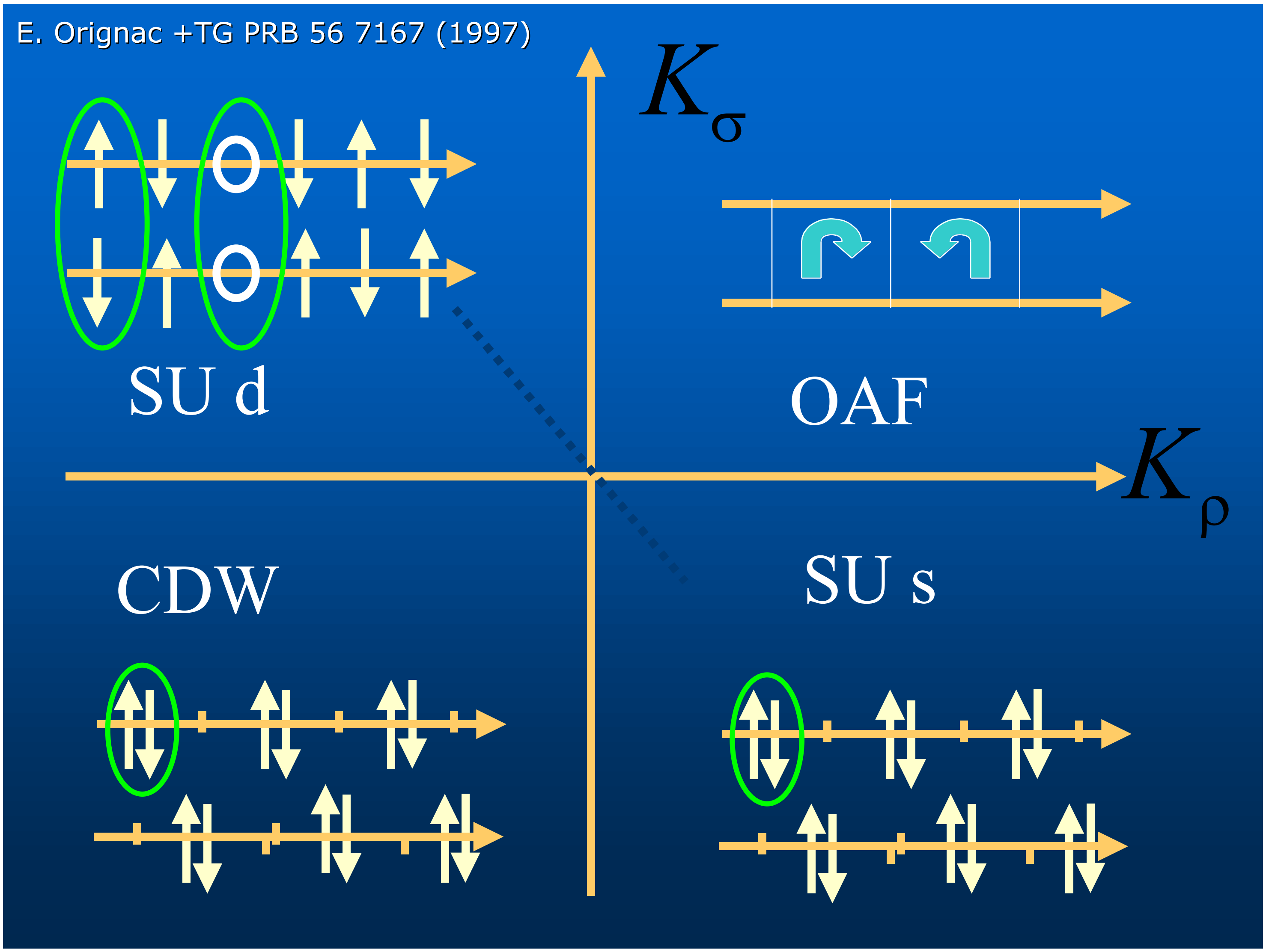
Bosonic Ladders: deconfinement



P. Donohue + TG PRB 63 180505(R) (2001)



Critical properties of the transition ?


E. Orignac +TG PRB 56 7167 (1997)
K_σ
K_ρ
SU d
OAF
CDW
SU s

Infinite number of chains

S. Biermann, A. Georges, TG, A. Lichtenstein, cond-mat 0201542

$$S_{\text{eff}} = -\int \int_0^\beta d\tau d\tau' \sum_{ij,\sigma} c_{i\sigma}^{+}(\tau) \mathcal{G}_0^{-1}(i-j, \tau - \tau') c_{j\sigma}(\tau') + \int_0^\beta d\tau H_{1\text{D}}^{\text{int}}[\{c_{i\sigma}, c_{i\sigma}^{+}\}], \tag{4}$$

$$G(k, i\omega_n) = \int d\epsilon_\perp \frac{D(\epsilon_\perp)}{i\omega_n + \mu - \epsilon_k - \Sigma(i\omega_n, k) - \epsilon_\perp}.$$

$$\text{Re}\, \sigma_\perp(\omega, T) \propto t_\perp^2 \int d\epsilon_\perp D(\epsilon_\perp) \int \frac{dk}{2\pi} \int d\omega' A(\epsilon_\perp, k, \omega') \times A(\epsilon_\perp, k, \omega + \omega') \frac{f(\omega') - f(\omega' + \omega)}{\omega}.$$

- Self consistent theory for Σ
- Feedback of $t_\perp$ in Σ (a priori important for deconfinement)
- Different from RPA

$$G(k,k_\perp,i\omega_n)=\frac{1}{i\omega_n-\varepsilon_k-\varepsilon_\perp(k_\perp)-\Sigma_{1D}(k,i\omega_n)}$$

- Difficult to solve the equations analytically

Incommensurate case

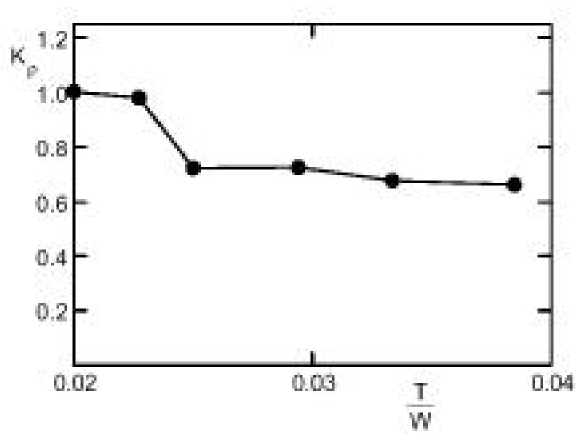


FIG. 2: Effective K_ρ vs. temperature in the doped case (filling $n \simeq 0.8$) for $U/W = 1.0$, $t_\perp/W = 0.14$.

$$T^* \sim \frac{t_\perp}{\pi}\left(\frac{t_\perp}{t}\right)^{\frac{\theta}{1-\theta}}$$

$$T^* \sim 0.5\frac{t_\perp}{\pi}$$

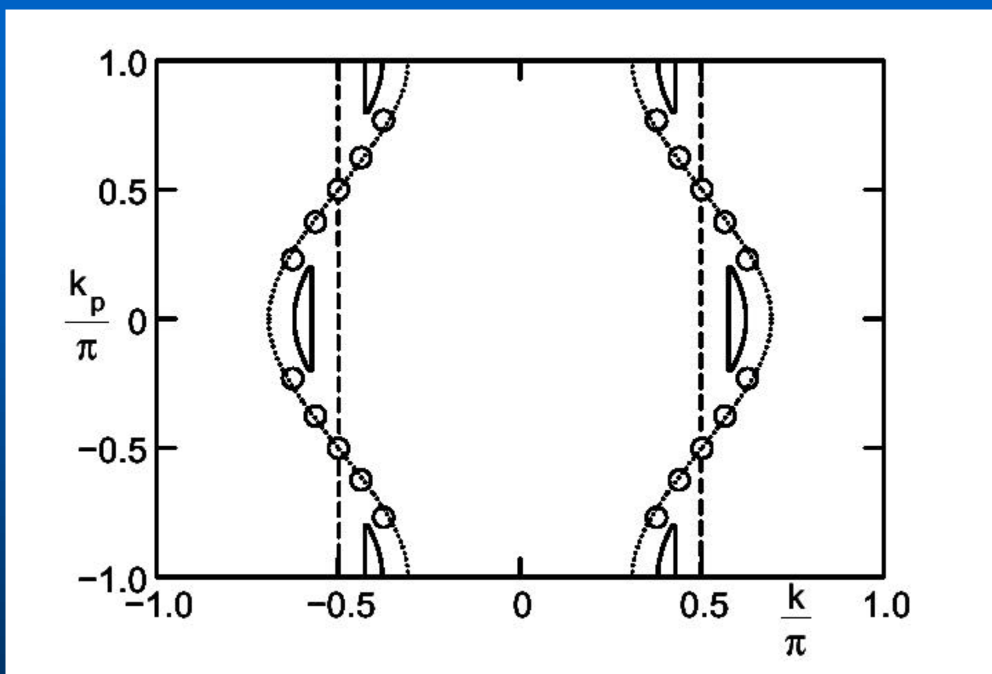
Commensurate case

TABLE II: Effective K_ρ at half-filling, as a function of $t_\perp/W$ for $U/W = 0.65$ and $T/W = 1/40$.

$t_\perp/W$	0.00	0.04	0.07	0.11	0.14	0.16	0.18
K_ρ	0.00	0.02	1.01	1.09	1.07	1.06	1.04

$$t_\perp^* \cup \Delta_{1D}$$

Fermi Surface



Z

$k_\perp/\pi$	0.23	0.38	0.50	0.62	0.77
$Z(k_\perp)$	0.78	0.77	0.76	0.77	0.79

Hall Effect

A. Lopatin, A. Georges, TG PRB 62 (00)

If no momentum relaxation (no umklapp) along the chains:

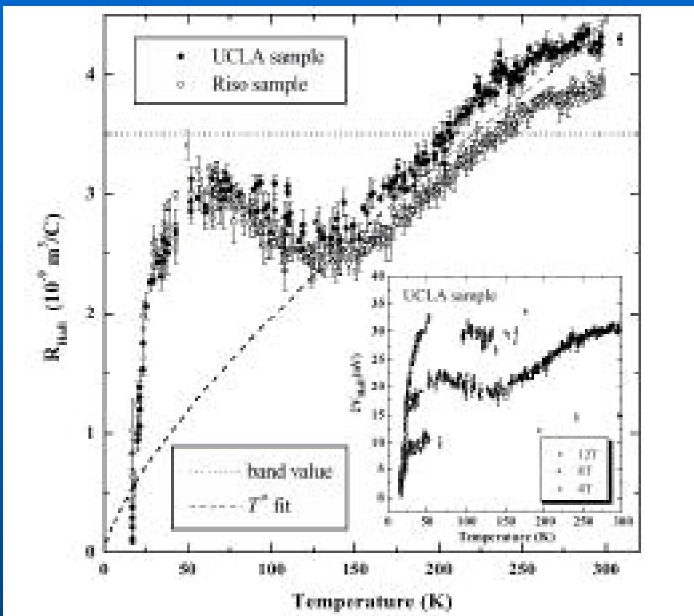
$$\rho_{yx} = \frac{H}{nec}\frac{2\alpha k_F}{v_F}.$$

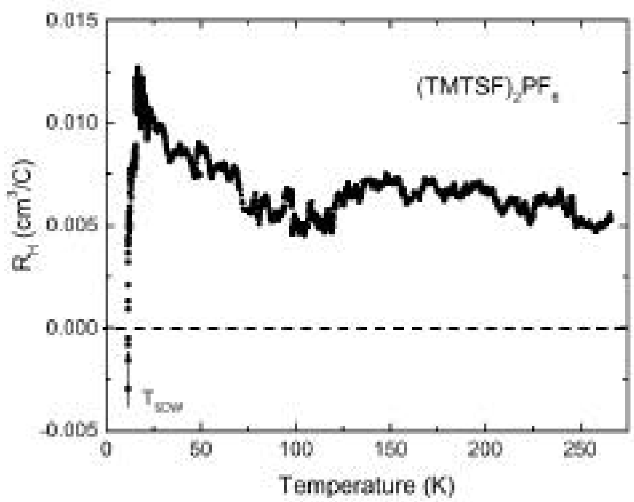
With umklapp : scaling expression for Hall

$$R_H(T) = R_H^0\left(1 + a_1\frac{g_3}{T^{1/x}} + a_2\frac{g_3^2}{T^{2/x}} + \cdots\right)$$

$$2x = 1/(1 - n^2 K_\rho)$$

Plot of Rh vs ρ_{xx}/T





J. Moser et al., PRL 84 2674 (00)

G. Mihaly et al., PRL 84 2670 (00)

Conclusions

- Fascinating (and poorly understood yet) crossover between 1D and higher dimensions
- Relevant for experimental systems
- Competition hopping/interactions : confinement
- chDMFT Good method to tackle the dimensional crossover