Kondo effect in transport through Aharonov-Bohm-Casher interferometers

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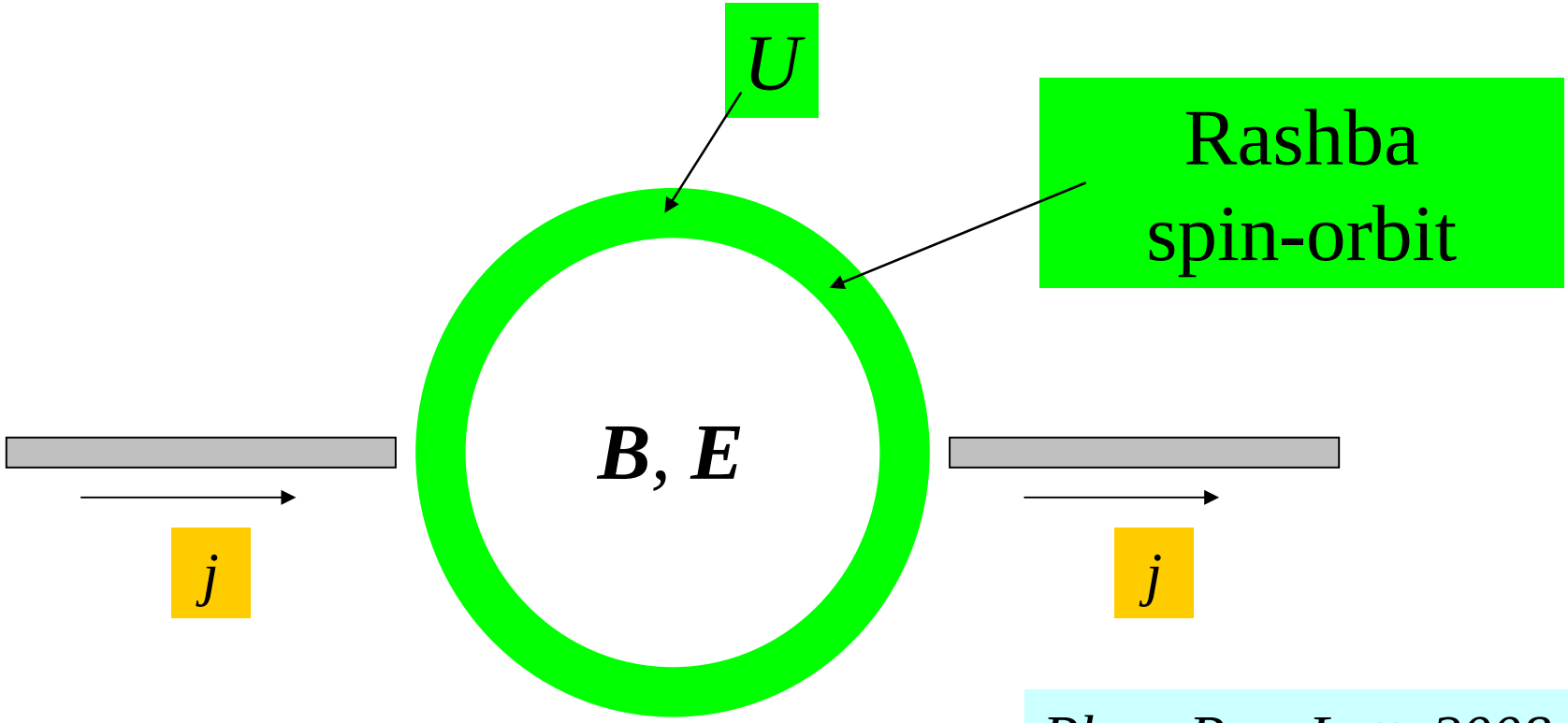


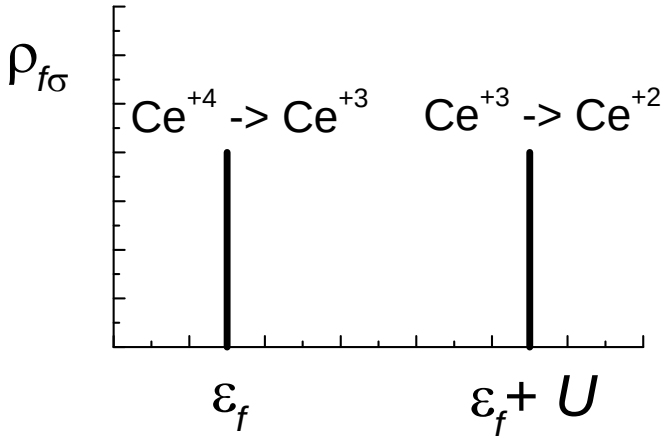
Phys. Rev. Lett. 2008

Scheme of the talk

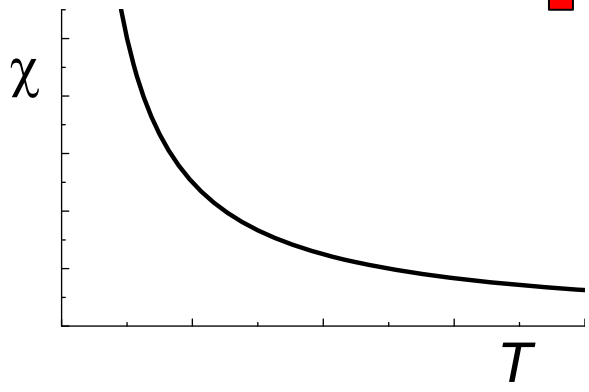
1) Anderson model and Kondo effect
2) Kondo resonances and conductance through quantum dots
3) Kondo antiresonances and spin filters
4) Interference effects in rings
5) Rashba SO coupling in one-channel rings
6) Conductance through rings pierced by magnetic and electric fields with Rashba SO coupling
7) Conclusions

Kondo effect

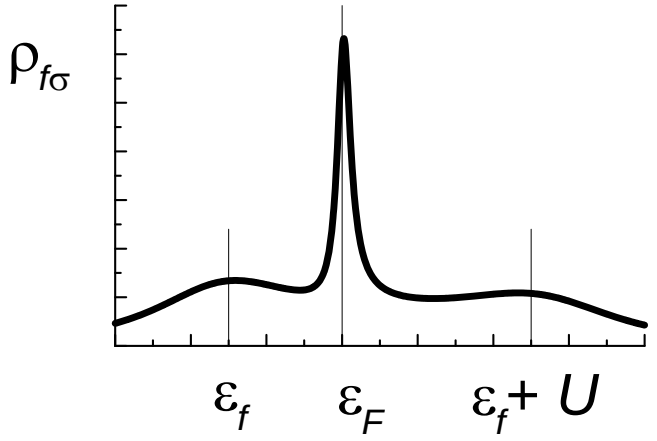
Isolated ion



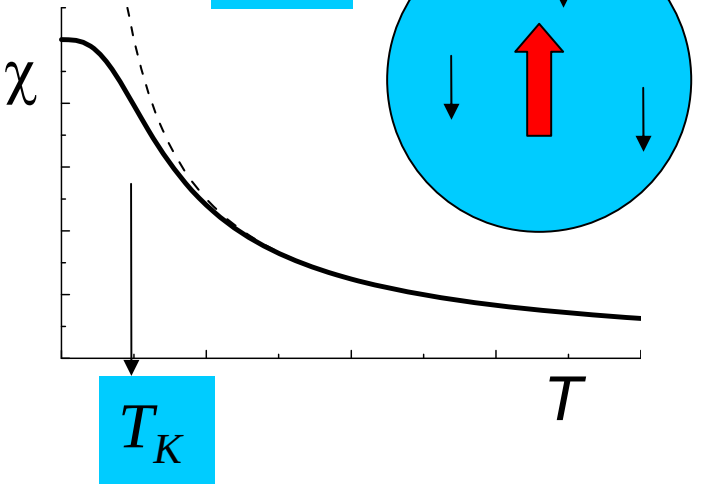
Ce^{+3} , j=5/2

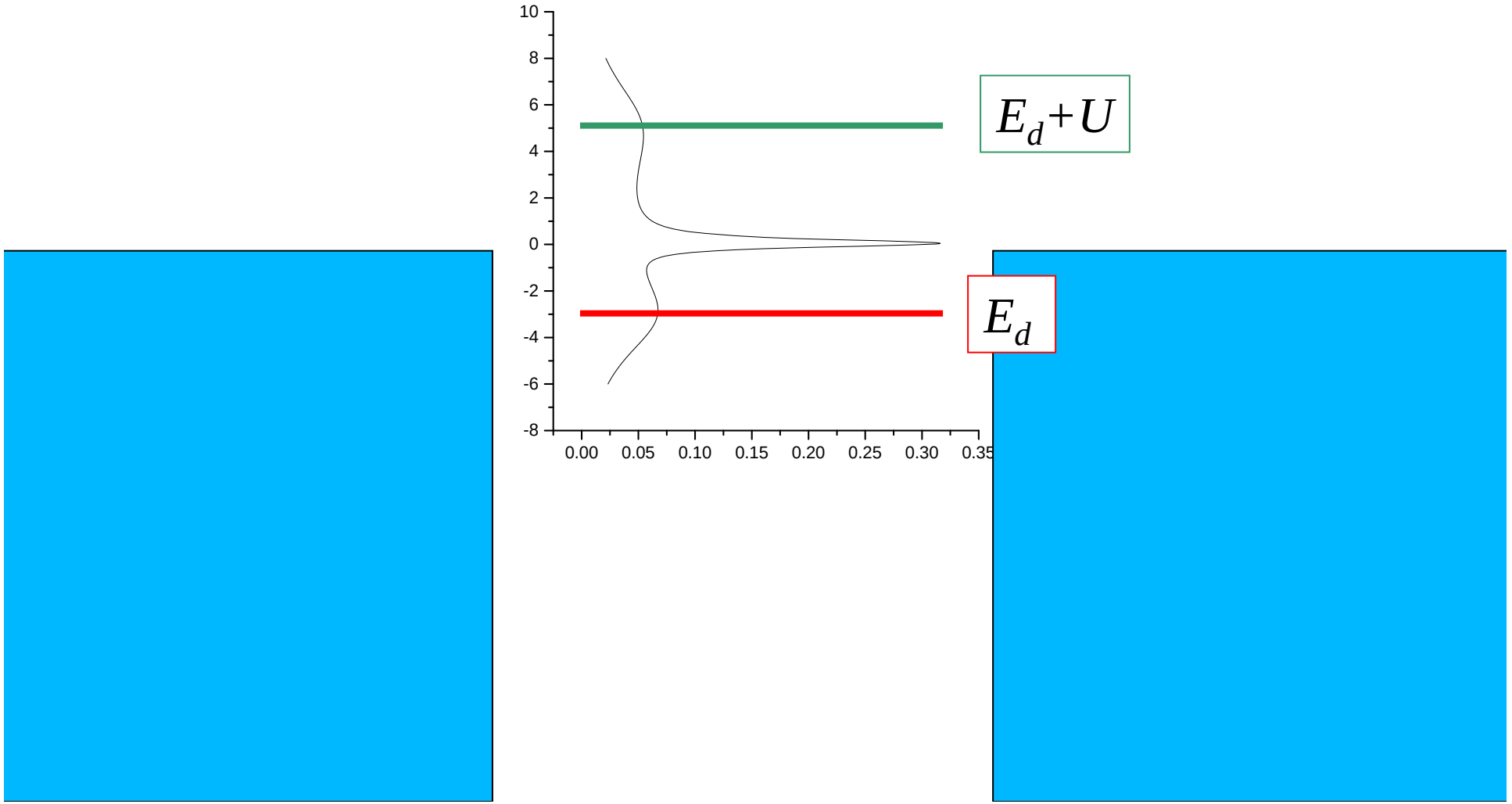


Impurity in metal

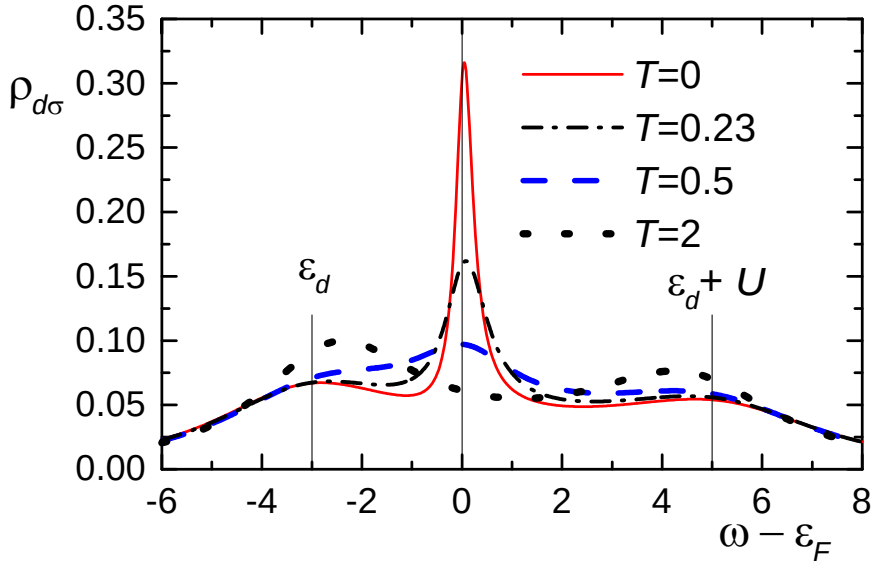


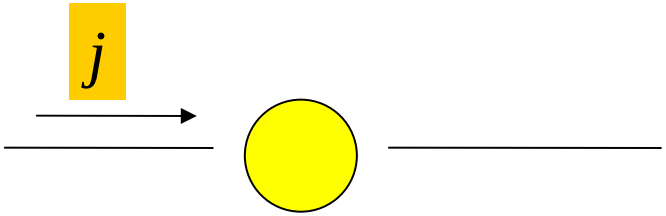
J=0




10
8
6
4
2
0
-2
-4
-6
-8
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
E_d+U
E_d

Spectral density
at the quantum dot

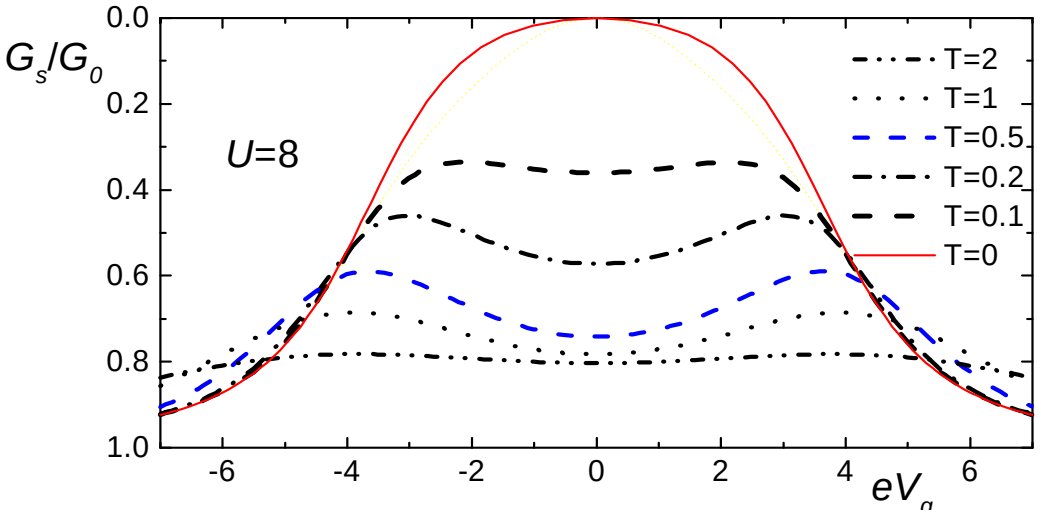




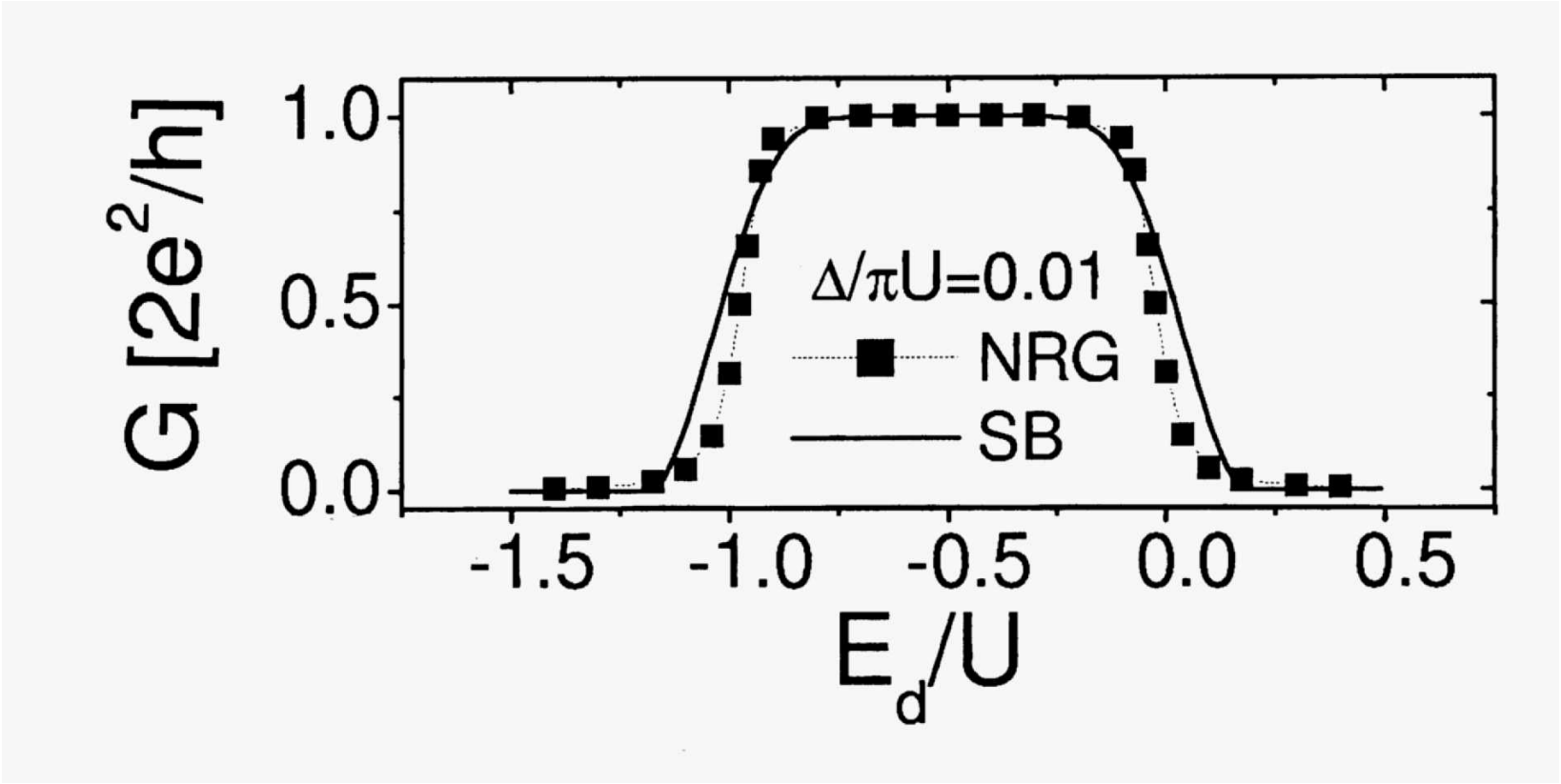
Conductance through
a quantum dot,
AAA, C. Proetto, PRB

$G_s = 1 - G_e$

T_K=0.23



Conductance through one quantum dot in the Kondo regime

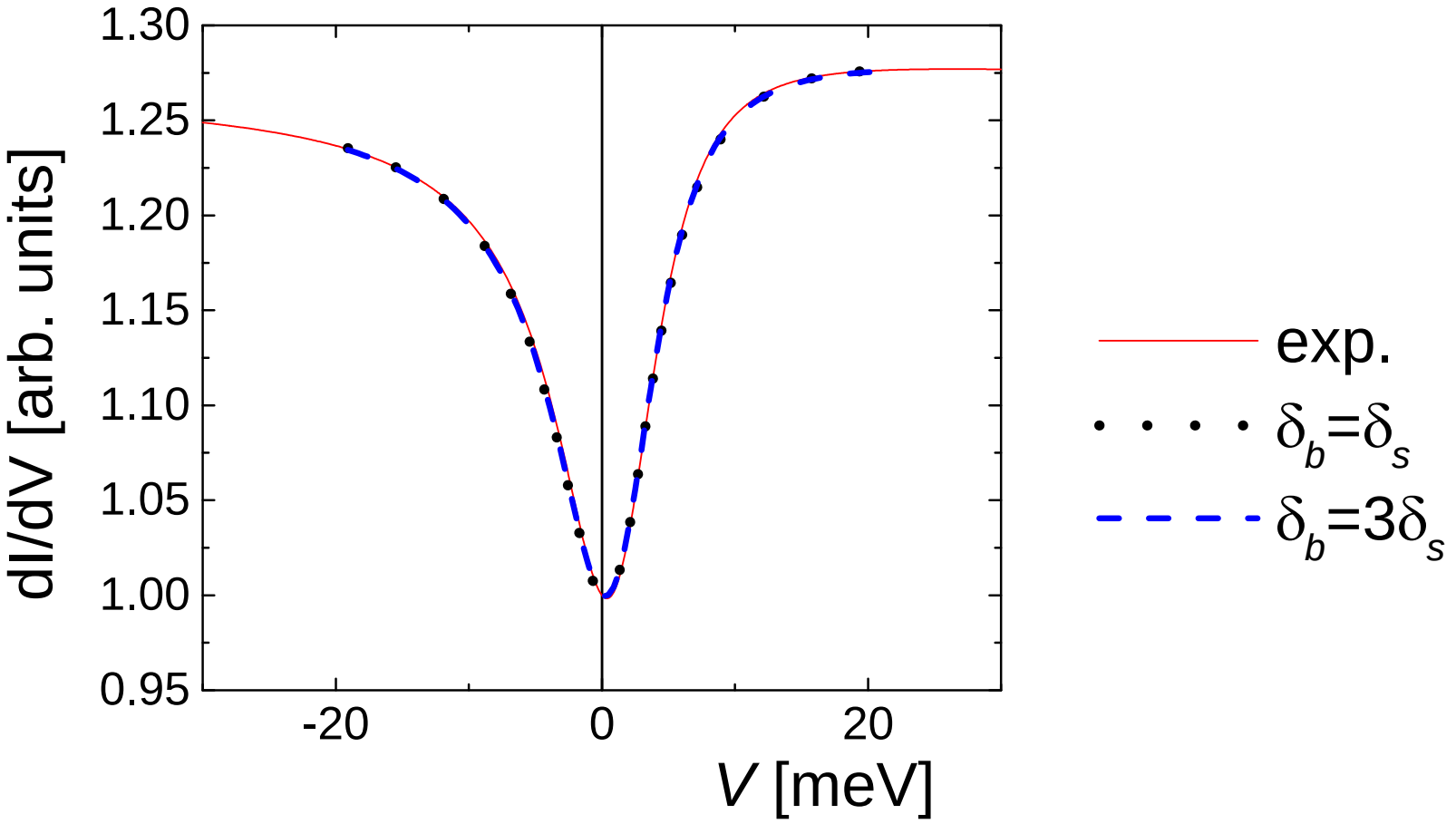


NRG: *W. Izumida, O. Sakai, and S. Suzuki, J. Phys. Soc. Jpn. 70, 1045 (2001)*

Kondo antiresonances

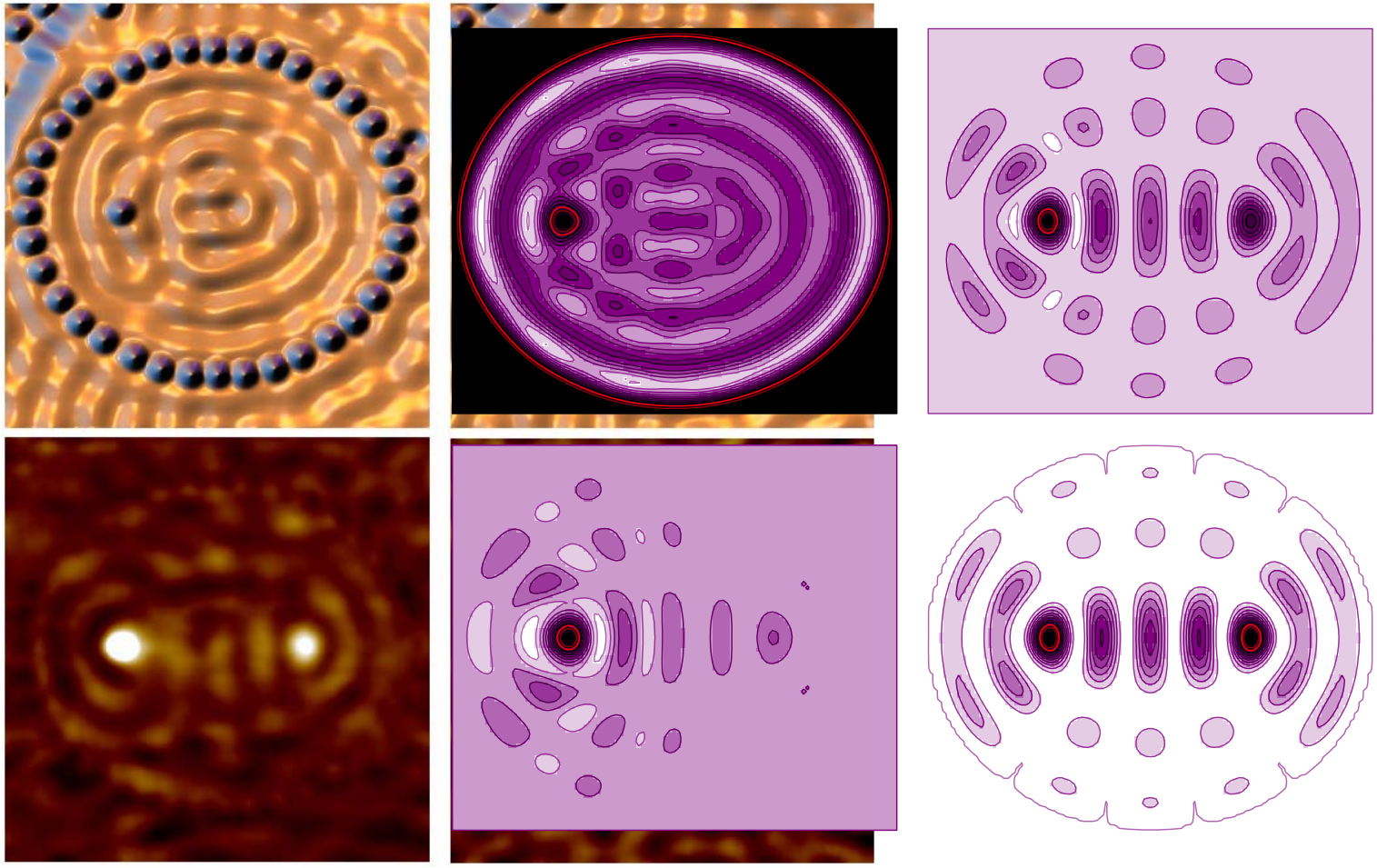
Co on Cu(111)

AAA, A.M. Lobos, J.Phys.:Condens. Matter 17, S1095 (2005)



Experiment:*Manoharan et al.*, *Nature 403, 512 (2000)*

Theory :*AAA*, *PRB 64, 121102 (R) (2001)*

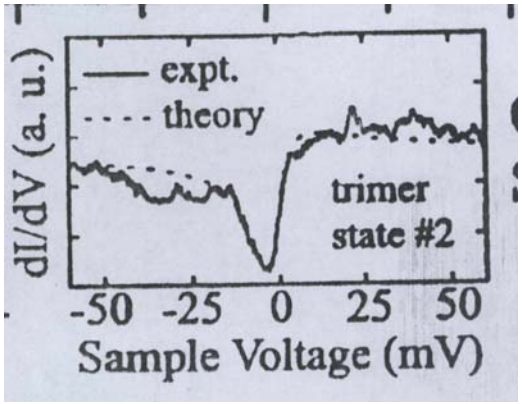


Cr atoms on Au(111), Experiment
Jamneala et al., PRL 87, 256804 (2001)

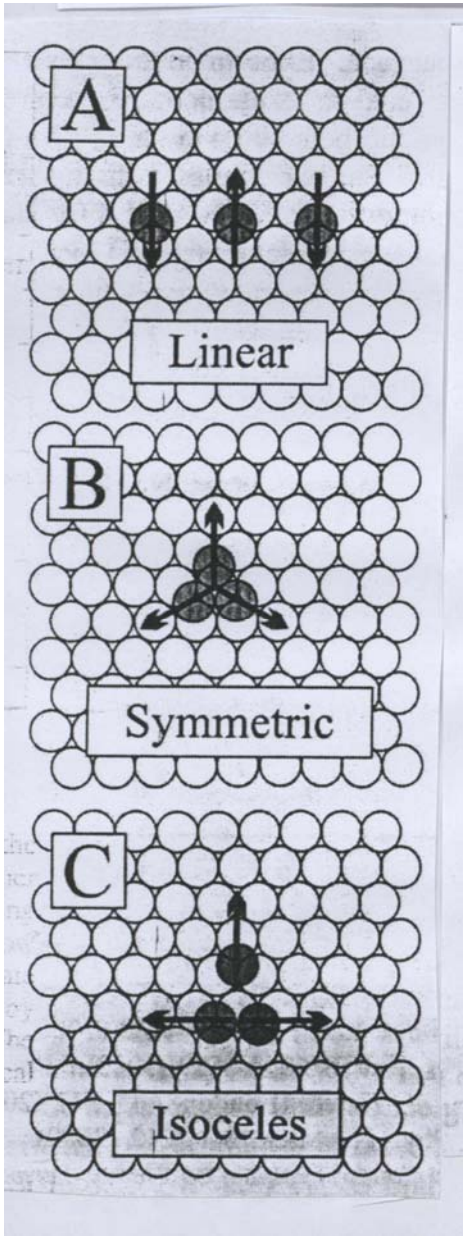
monomer

dimer

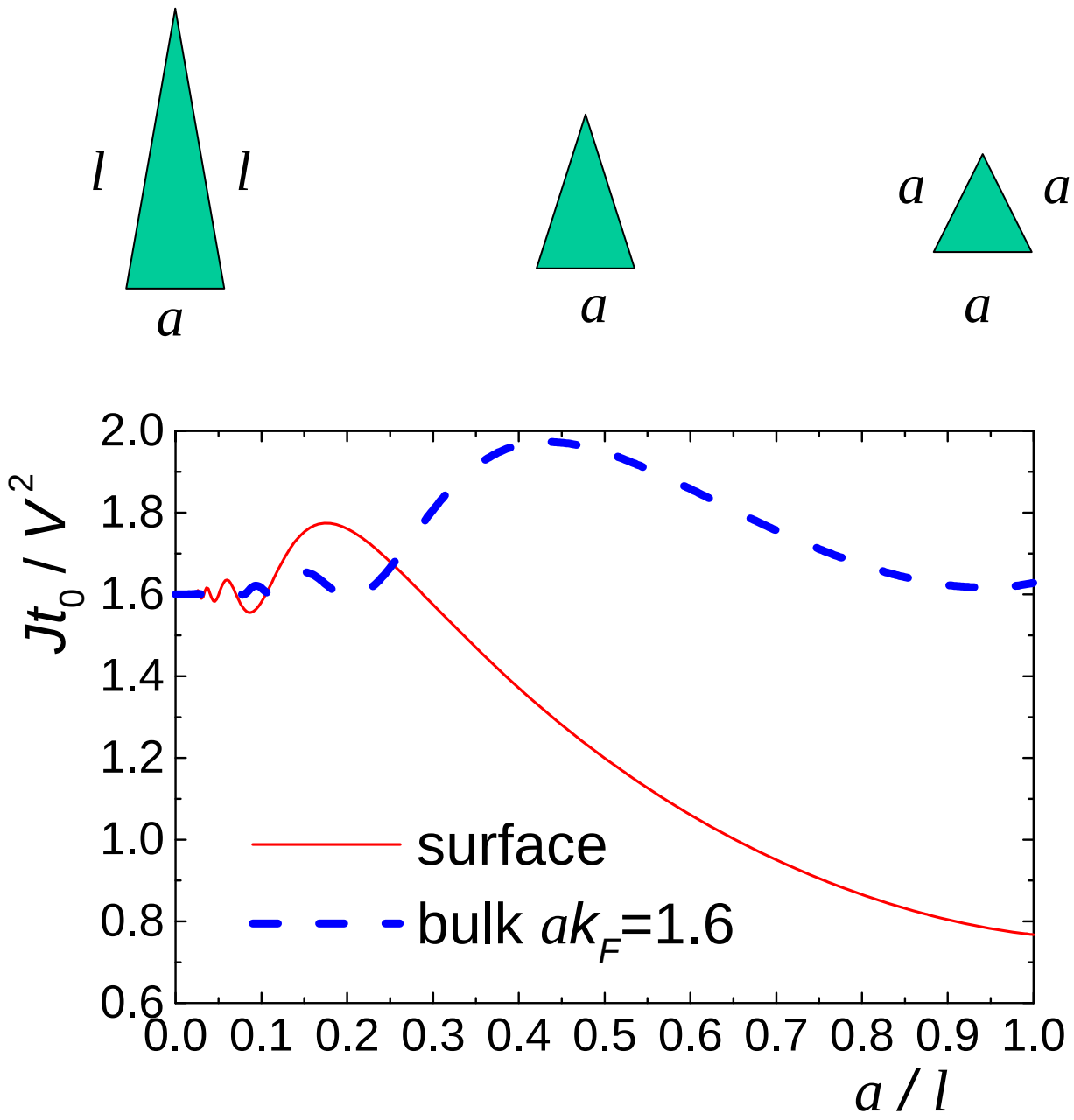
$T_K < 7$ K



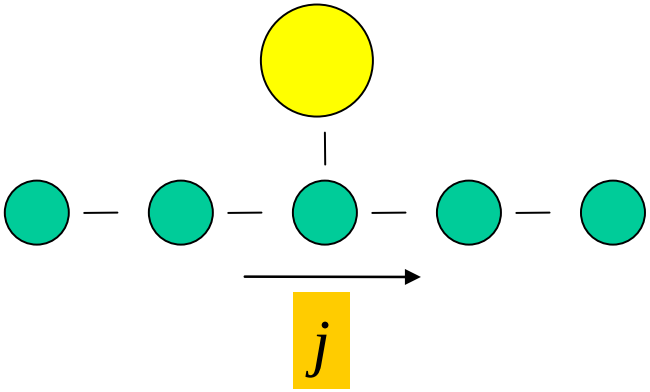
$T_K \sim 50$ K



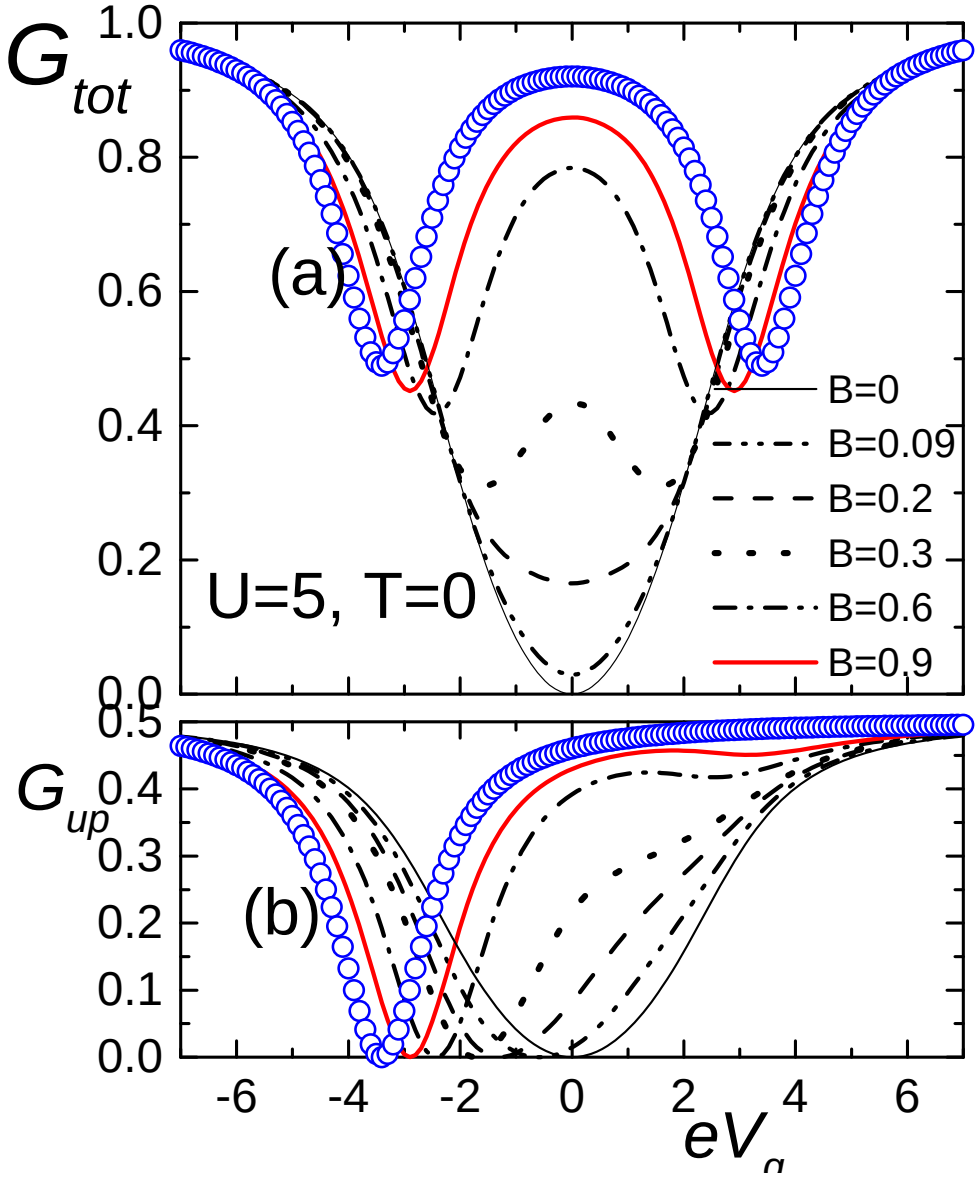
Theory *AAA, PRL 96, 096804 (2006)*


l
l
a
a
a
a
a
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
Jt_0 / V^2
surface
bulk ak_F=1.6
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
a / l

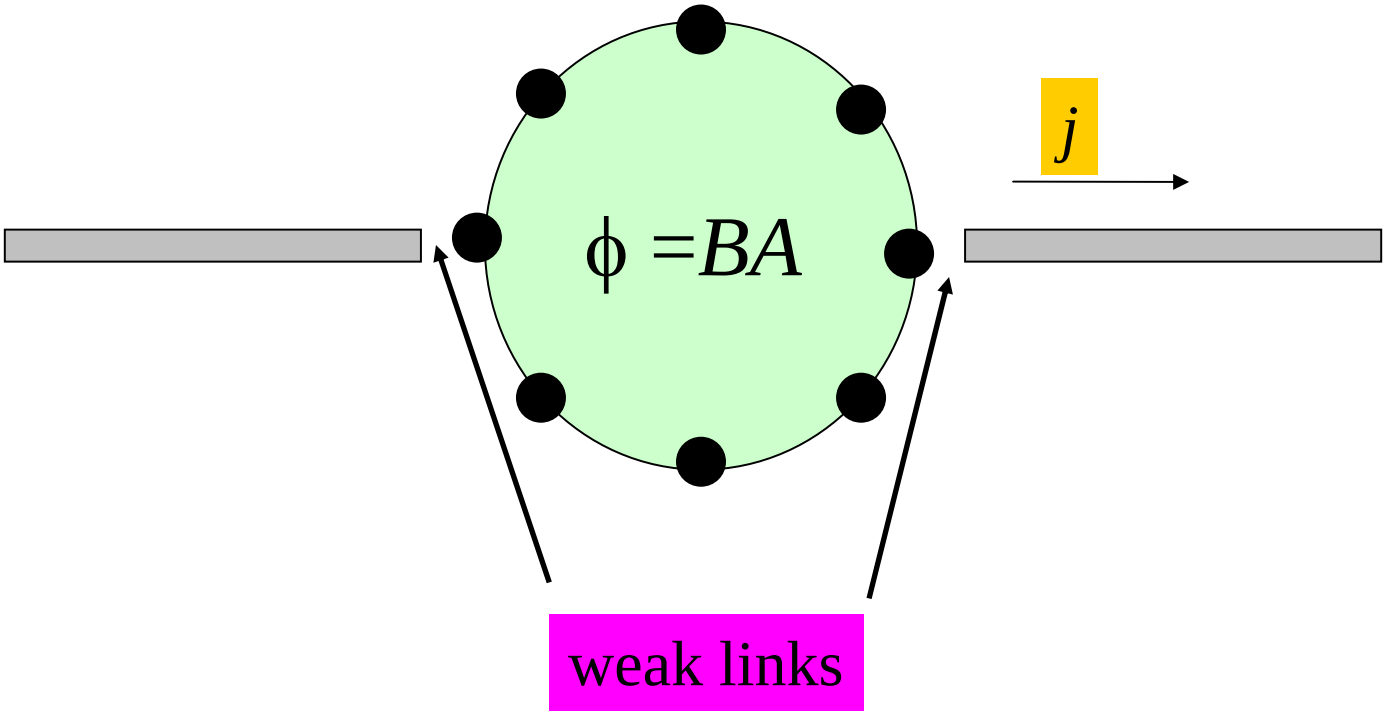
Side dot as a spin filter



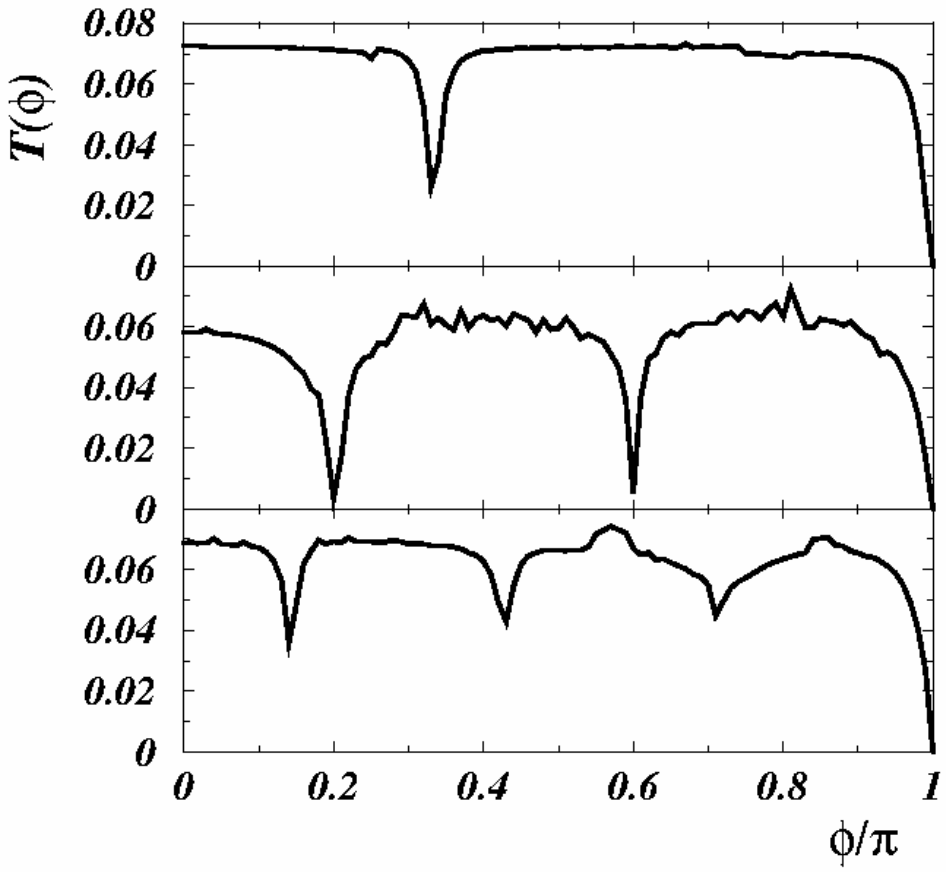
M.E. Torio et al., EPJB
AAA, L.A. Salguero, PRB
(2004)



Effects of interference



Transmittance integrated over an energy window in *t-J* model



$N = 4$

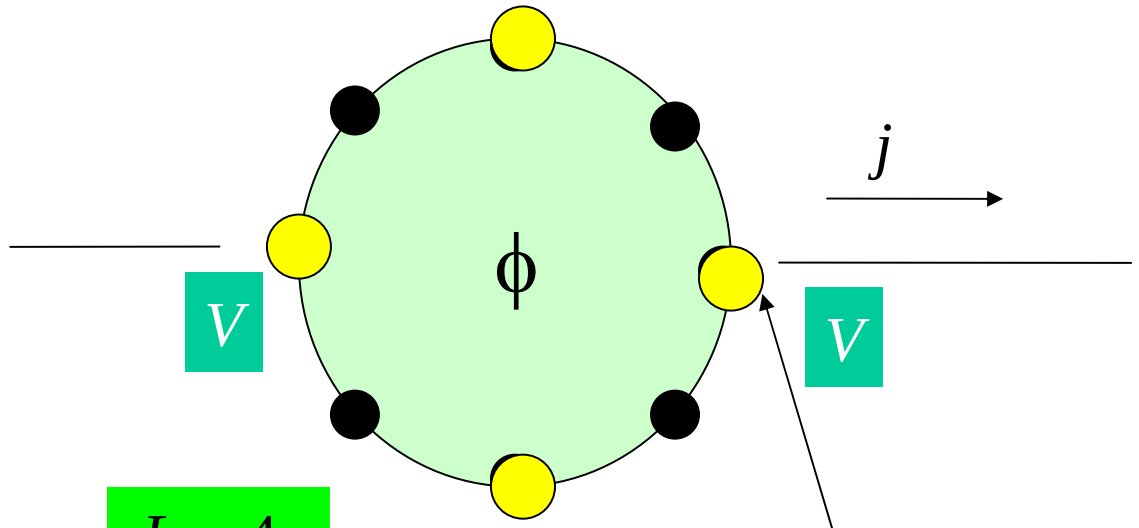
$N = 6$

$N = 8$

K. Hallberg, AAA, A.P. Kampf, B. Normand, PRL 93, 076801 (2004)

E.A. Jagla and C.A. Balseiro, PRL 70, 639 (1993)

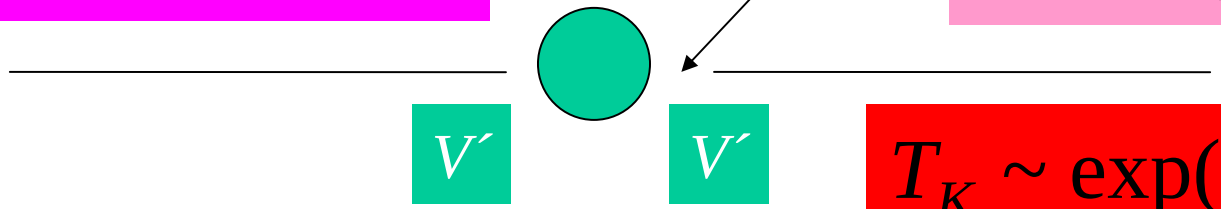
Measuring the topological charge transition in the ionic Hubbard model



$L = 4n$

weak links

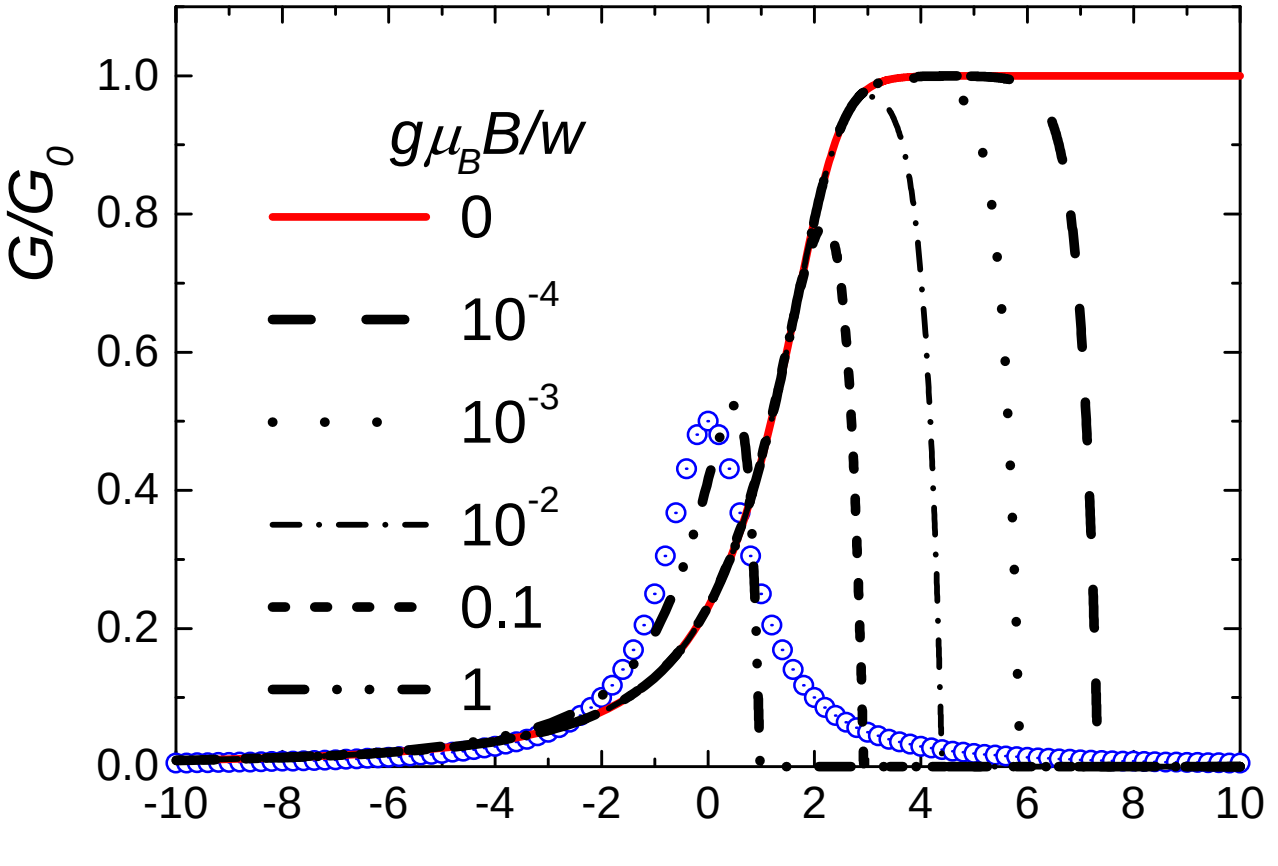
Mapping to an effective Anderson



AAA et al., PRL (2004)

$T_K \sim \exp(-\rho |E_d| / V'^2)$

Conductance effective Anderson



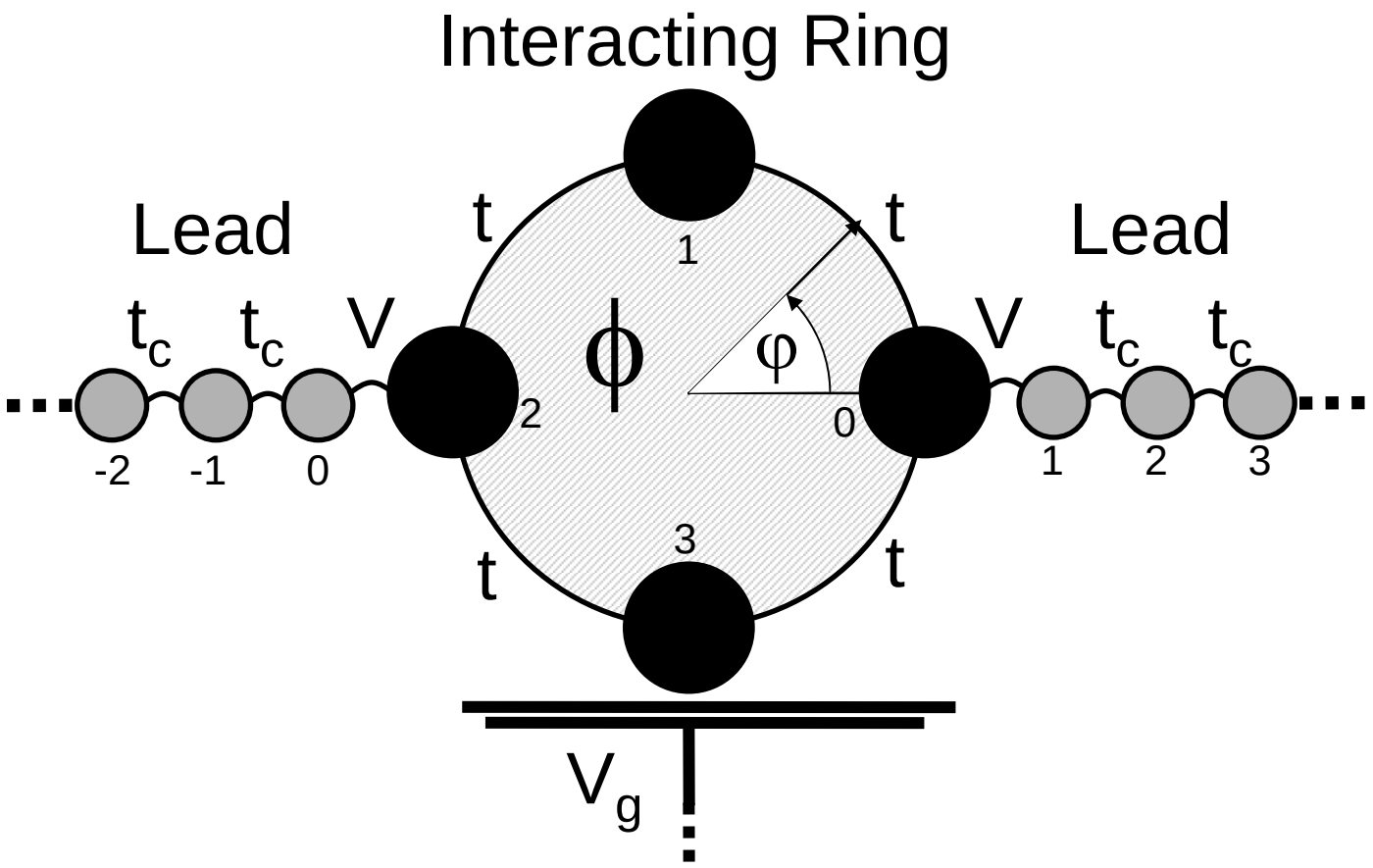
$G_0 = 2e^2/h$

$w \sim A$

R.L.Width w proportional to quasiparticle weigth A

Kondo effect recovered but interference lost

Aharonov-Bohm-Casher interferometers



A.M. Lobos, AAA, Phys. Rev. Lett. 2008

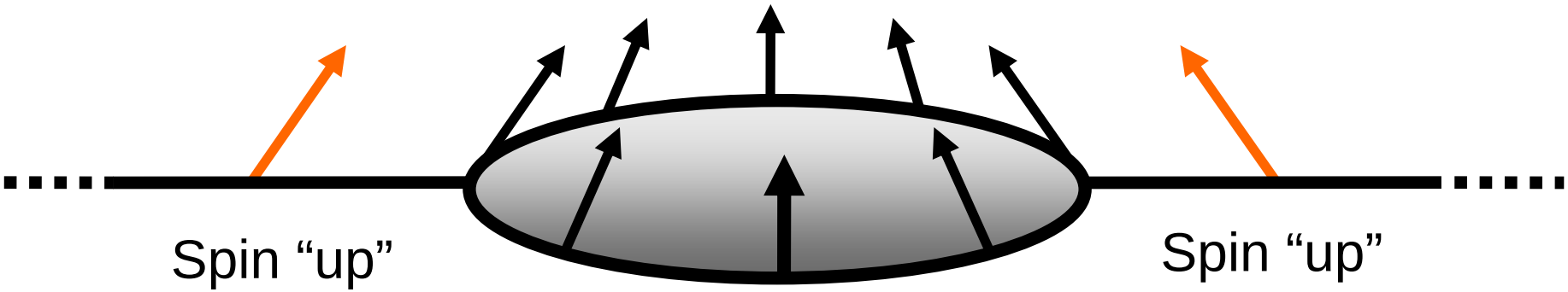
$$H_{\mathrm{SOC}} = \alpha\vec{\sigma}\cdot\vec{\mathrm{E}}\times(\vec{\mathrm{p}} - e\vec{\mathrm{A}})$$

$$H_{tb} = \alpha E_z \hbar/(2a)\sum_i [i\cos\varphi(d^\dagger_{i+1\uparrow}d_{i\downarrow} + d^\dagger_{i+1\downarrow}d_{i\uparrow}) + \sin\varphi(d^\dagger_{i+1\uparrow}d_{i\downarrow} - d^\dagger_{i+1\downarrow}d_{i\uparrow}) + \mathrm{H.c.}]$$

$$H^c_{NI} = \hbar\Omega\sum_j\left[-i\frac{\partial}{\partial\varphi} - \frac{\phi}{\phi_0} + \frac{\gamma}{2}\sigma_r(\varphi)\right]^2 \longrightarrow H^c_{NI} = \hbar\Omega\sum_j\left[-i\frac{\partial}{\partial\varphi}\right]^2$$

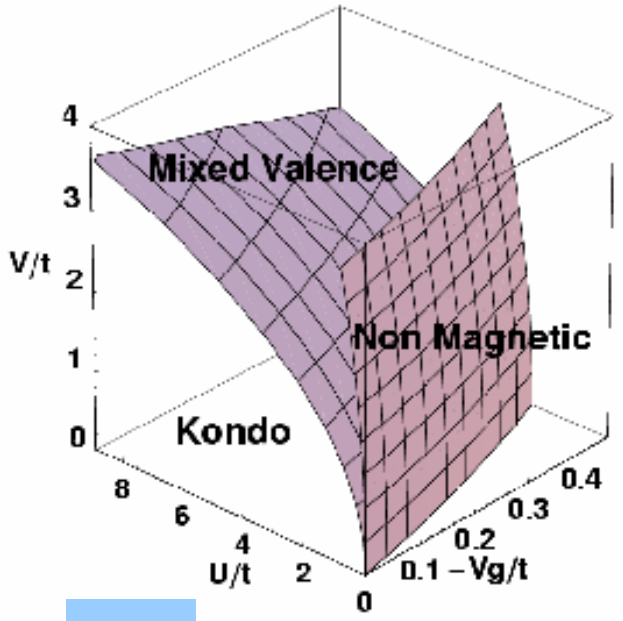
$$\begin{aligned} H'_U \;=\; & -\sum_{i=0,\sigma}^{N-2} t\left[d^\dagger_{i+1\sigma}d_{i\sigma} + \mathrm{H.c.}\right] - t\left[\exp i(\Phi_{AB} + \sigma\Phi_{AC})d^\dagger_{0\sigma}d_{N-1,\sigma} + \mathrm{H.c.}\right] \\ & + U\sum_i d^\dagger_{i\uparrow}d_{i\uparrow}d^\dagger_{i\downarrow}d_{i\downarrow}, \end{aligned}$$

$$\Phi_{AC} = \sqrt{\pi^2 + R^2} - \pi, \qquad R \sim \alpha$$


Spin “up”
Spin “up”

☞ =

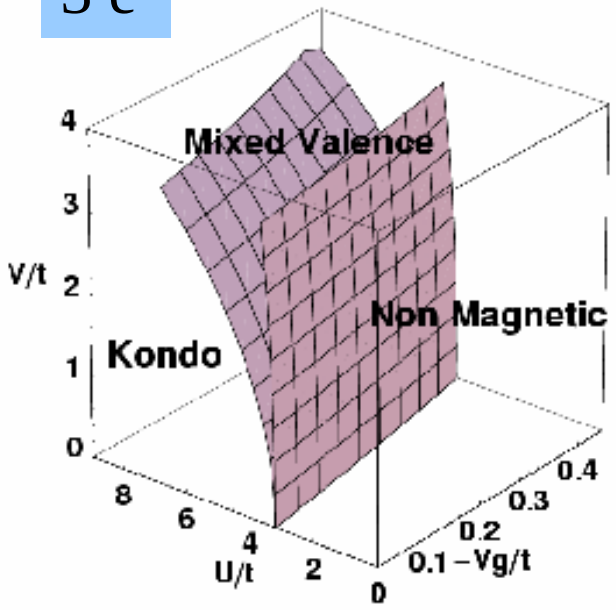
0


Mixed Valence
Non Magnetic
Kondo
V/t
U/t
0.1 – Vg/t

4 e-

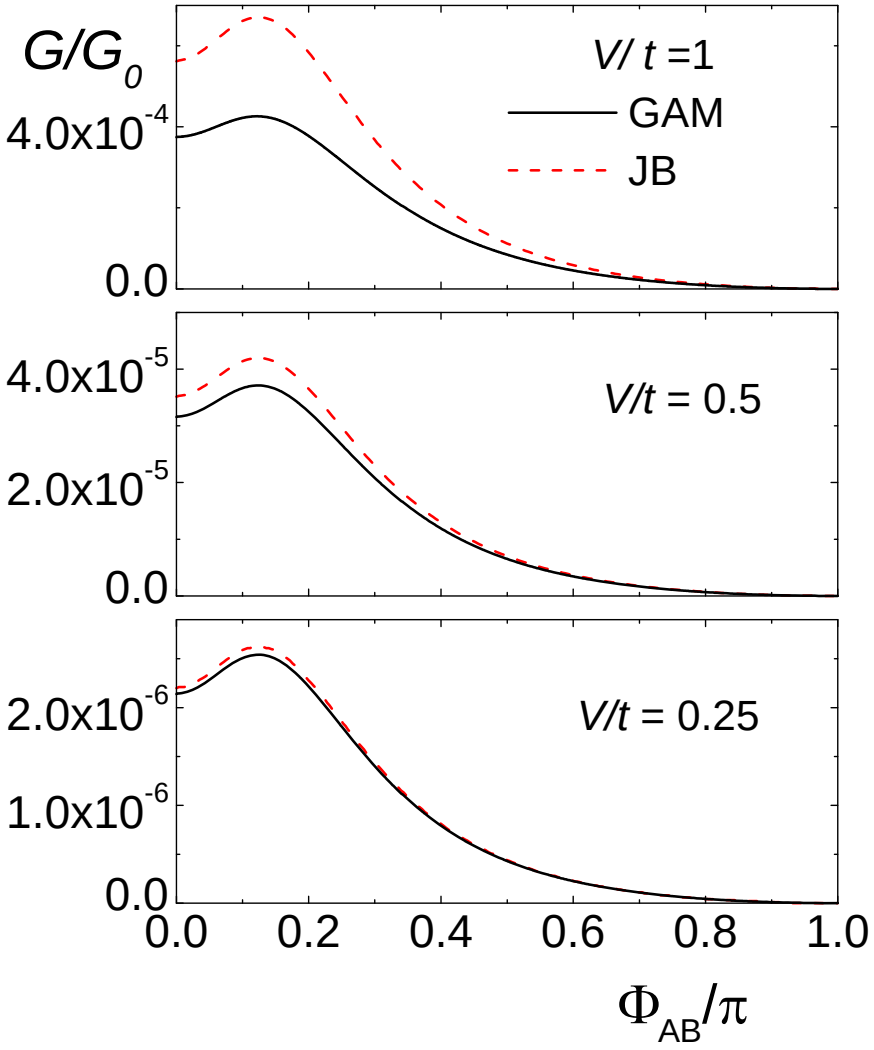
3 e-

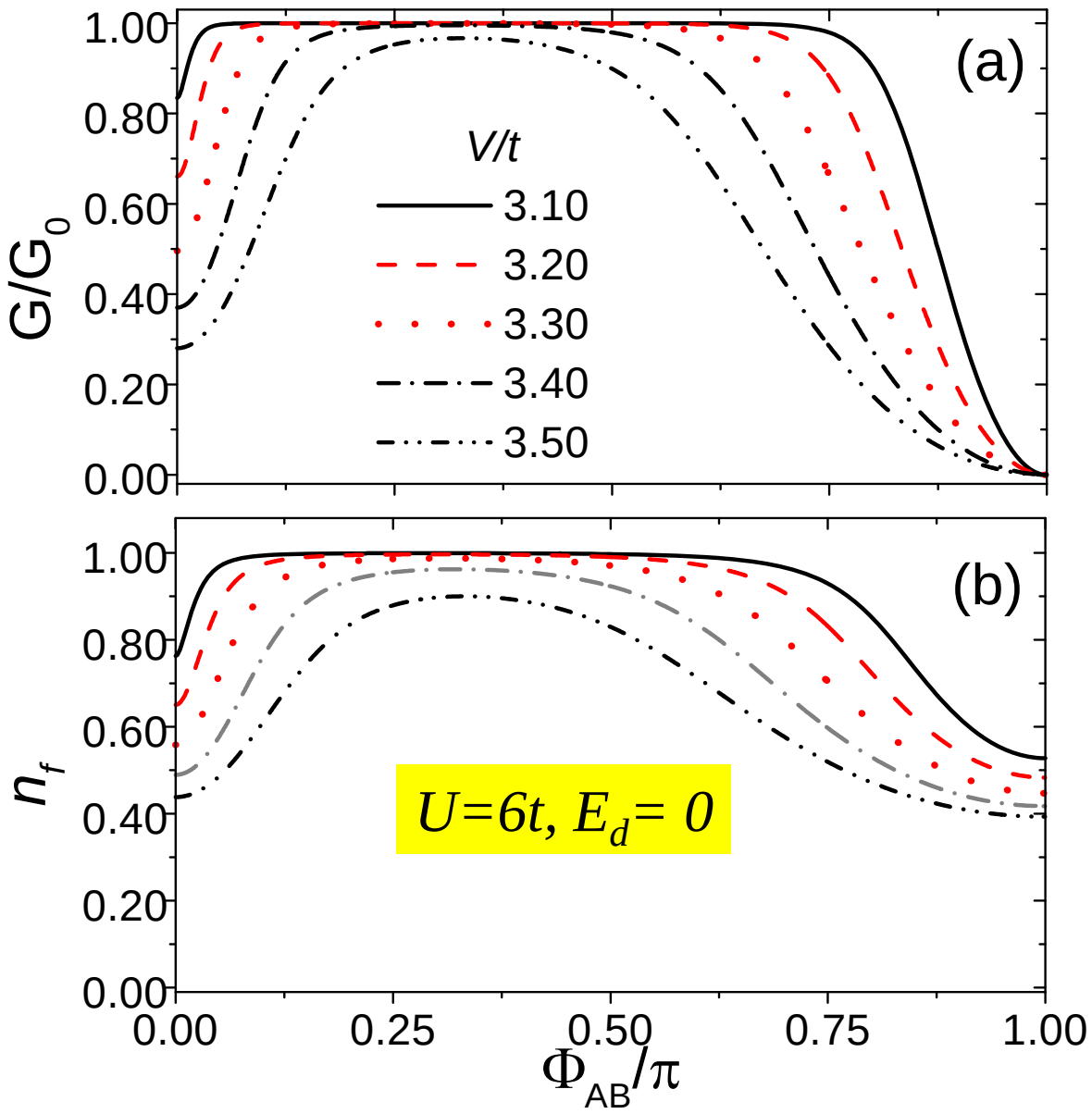
☞ = ☞ $_0$/2

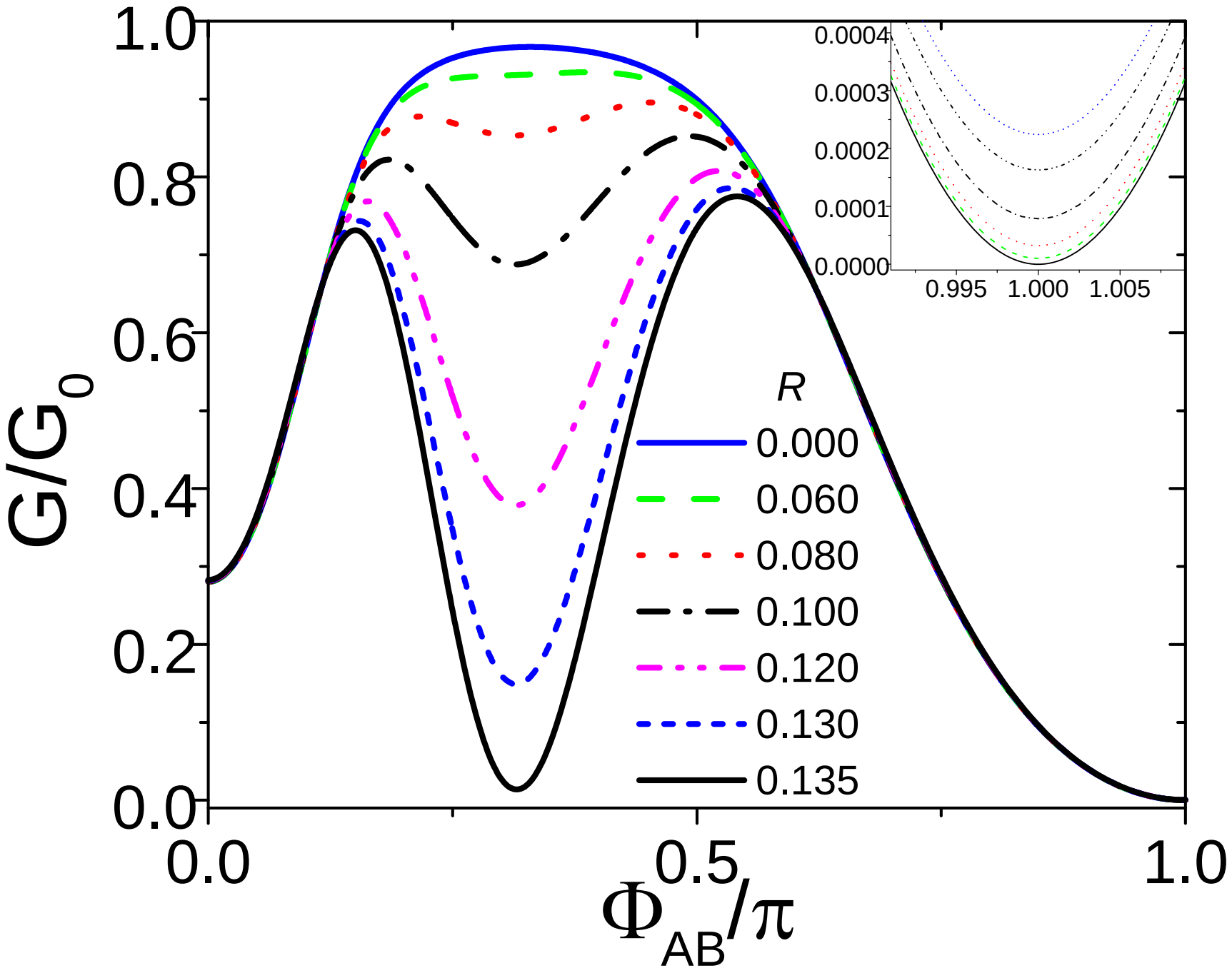

Mixed Valence
Non Magnetic
Kondo
V/t
U/t
0.1 – Vg/t

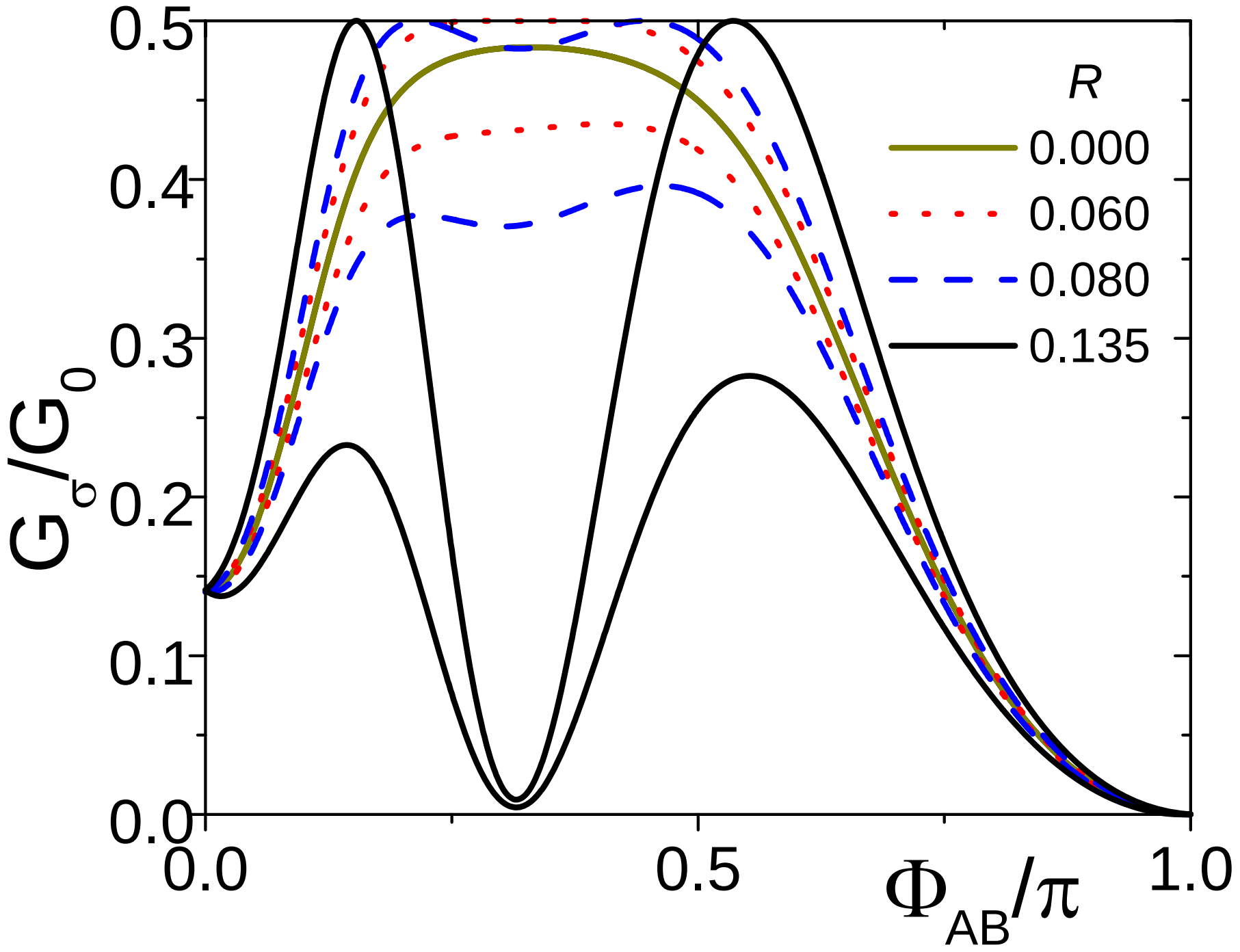
Conductance in the non-magnetic regime

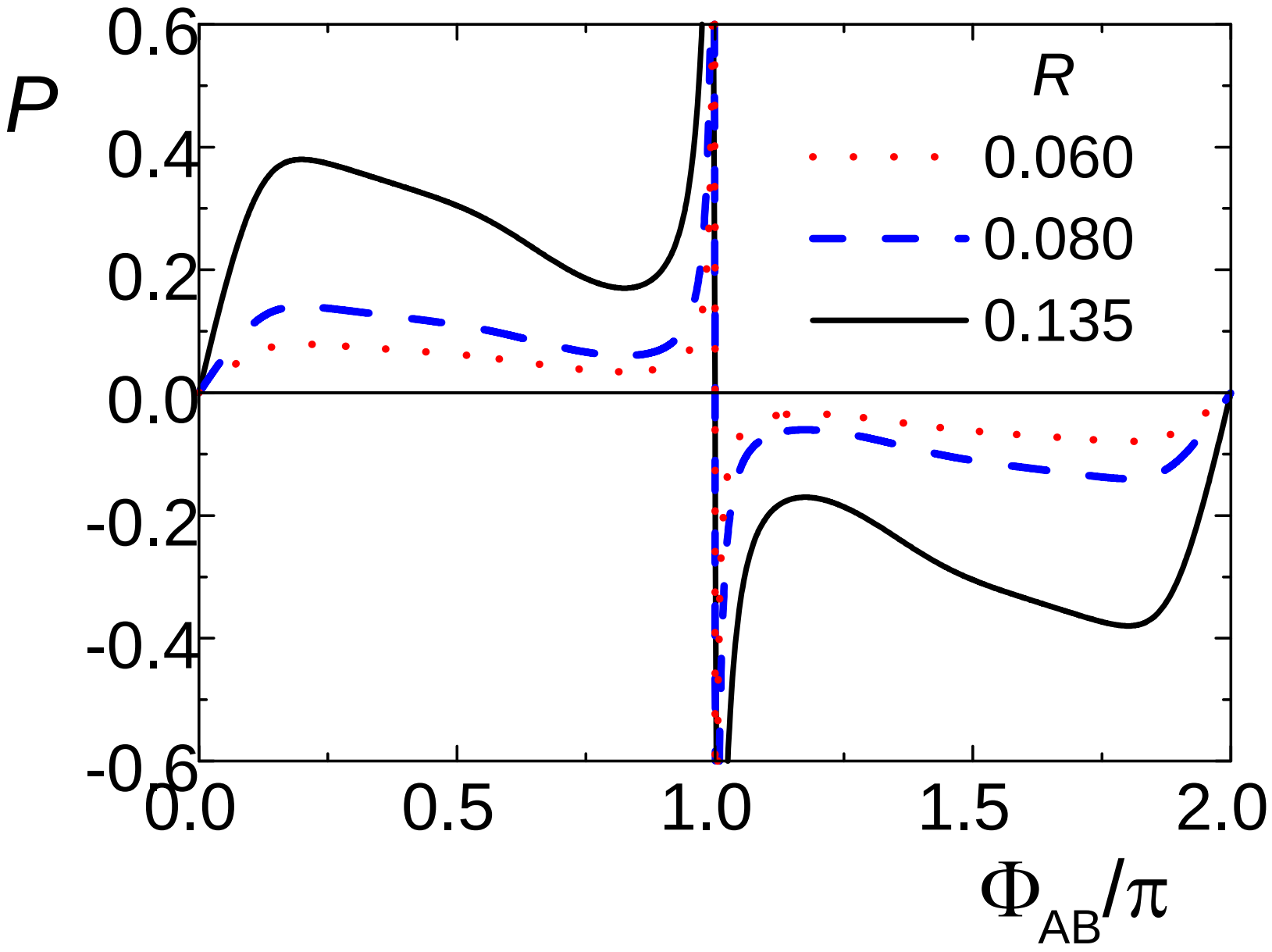
$U=2t,\ E_d=-0.8t$




(a)
(b)
G/G0
ηf
V/t
3.10
3.20
3.30
3.40
3.50
U=6t, Ed= 0
1.00
0.80
0.60
0.40
0.20
0.00
0.00
0.25
0.50
0.75
1.00
ΦAB/π


1.0
0.8
0.6
0.4
0.2
0.0
G/G0
0.0
0.5
1.0
ΦAB/π
0.0004
0.0003
0.0002
0.0001
0.0000
0.995
1.000
1.005
R
0.000
0.060
0.080
0.100
0.120
0.130
0.135


0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.5
1.0
G_σ/G_0
Φ_{AB}/π
R
0.000
0.060
0.080
0.135


P
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.0
0.5
1.0
1.5
2.0
Φ_AB/π
R
0.060
0.080
0.135

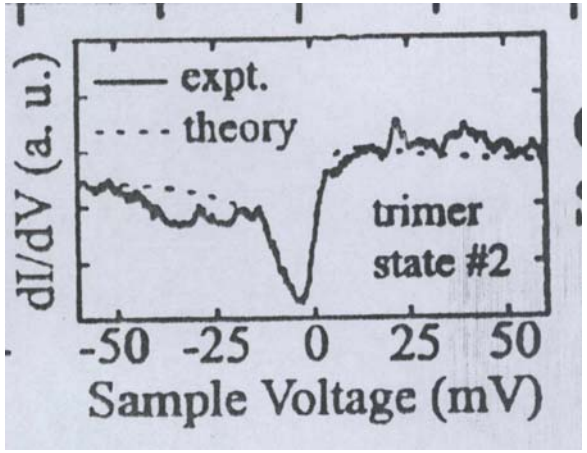
Conclusions

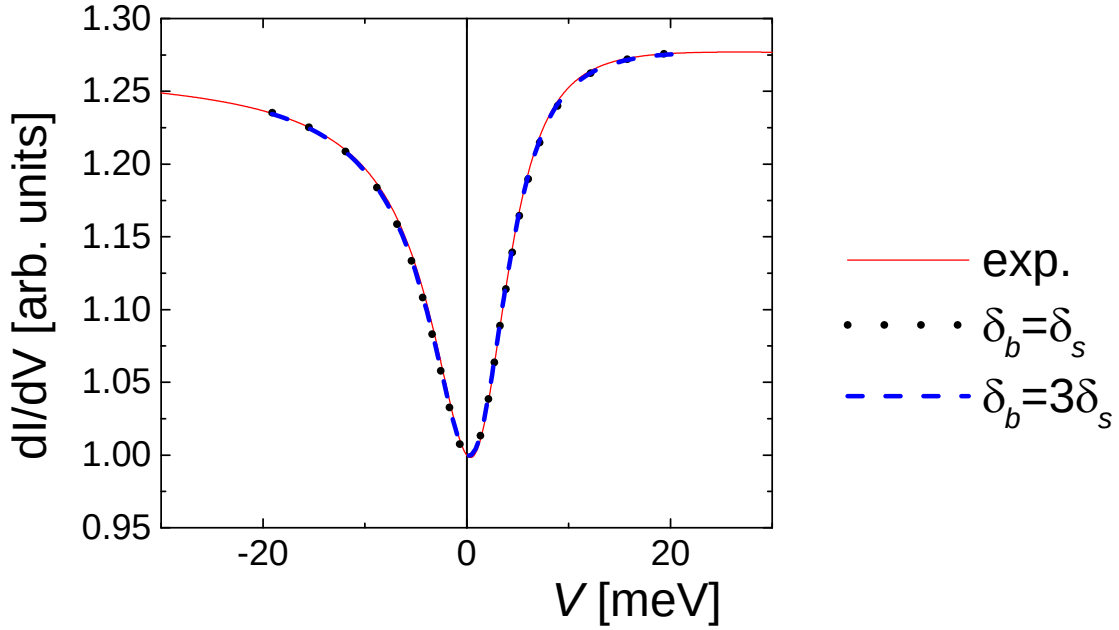
For rings with one conduction channel, the Rashba spin-orbit coupling can be absorbed in the boundary conditions using a spin quantization axis that depends on the position

Mapping to an appropriate effective one-site generalized Anderson model allows to describe both, Kondo effect and interference phenomena.

Kondo effect plus Rashba spin-orbit coupling might be used to control the spin

Isosceles Cr trimer on Au(111)





Co on Cu(111)

AAA, A.M. Lobos, J.Phys.:Condens. Matter 17, S1095 (2005)

- turn on canyon
- ATI ->schemes-> switch among displays
- switch again
- turn off canyon