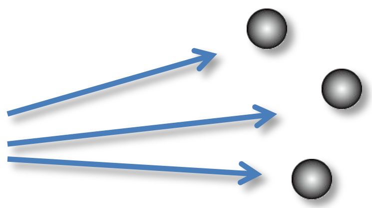


Nonequilibrium current in orbital-degenerate Anderson dot with a Hund rule's coupling

<u>Rui Sakano</u>

Y. Nishikawa, A. Oguri, A. C. Hewson, and S. Tarucha

Related papers:

RS, Fujii, and Oguri, PRB **83**, 075440 (2011)

RS, Oguri, Kato, and Tarucha, PRB **83**, 241301(R) (2011)

Oguri, RS, and Fujii, PRB **84**, 113301 (2011)

Study on transport in mesoscopic systems

- **Advancement in observation technique**

Time averaged current $\langle I \rangle$ → Beyond linear response

Study on *current fluctuation*

$$\delta I(t) = I(t) - \langle I \rangle$$

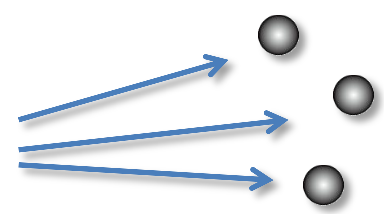
- **Shot noise** = current-current correlation at *T*=0

$$S \equiv \int dt \, \langle \delta I(t)\, \delta I(0) + \delta I(0)\, \delta I(t) \rangle$$

"effective charge e^*": *charge unit* of curret carrying particle

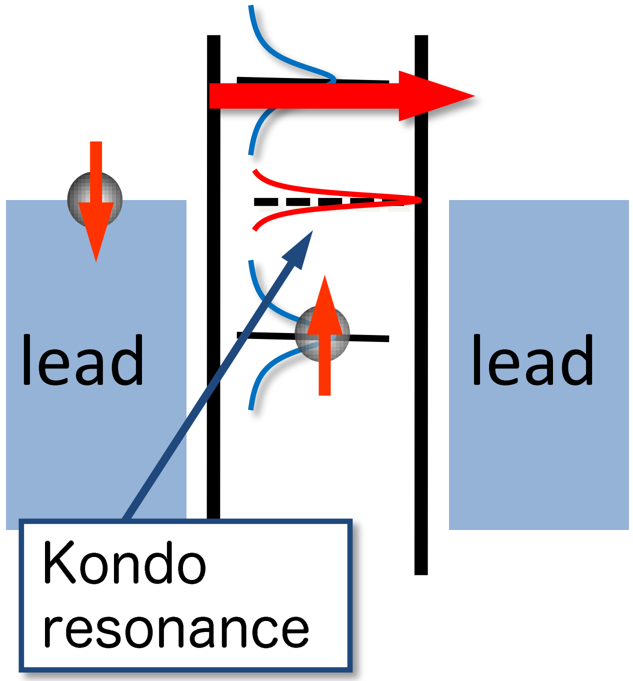
$$S = 2e^* \langle I \rangle$$

Information *not* in *equilibrium*



Y. M. Blanter and M. Büttiker, Phys. Rep. **336**, 1 (2000)

Effective charge due to Kondo dot?



- **Bias-linear current**

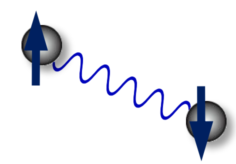
  Tunneling via *Kondo resonant level*

- **Finite bias voltage** Access to excited state

  1. Scattering by *Kondo resonant level*

     Single quasiparticle <charge $e_1^* = e$>

  2. *Residual Coulomb interaction $\tilde{U}$*



Quasiparticle pair in singlet state **<charge** $e_2^* = 2e$**>**

Averaged contribution of e_1^* and e_2^*
For backscattering current

Fano factor

$$F_b = S/2\langle I_b\rangle = 5/3$$

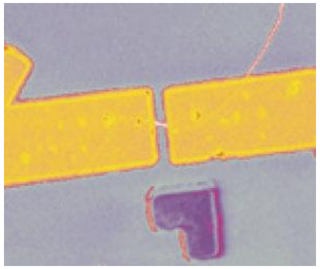
Theory: E. Sela, *et al.*, PRL **97**, 086601 (2006); A. O. Gogolin and A. Komnik, PRL **97,** 016602 (2006)

Experiment: O. Zarchin, *et al.,* PRB **77**, 241303(R) (2008); Yamauchi, *et al.*, RS, PRL **106**, 176601 (2011)

Our work

"M-fold orbital-degenerate Anderson model"

- Half-filling
- Full screening



Carbon nanotube dot

$$\mathcal{H}_A = \sum_{klm\sigma} \varepsilon_k c^{+}_{klm\sigma} c_{klm\sigma} + \sum_{m} \epsilon_d d^{+}_{m\sigma} d_{m\sigma} + \sum_{klm} (v_l d^{+}_{m\sigma} c_{klm\sigma} + \mathrm{H.c.})$$

$$+ \sum_{m} \boldsymbol{U} d^{+}_{m\uparrow} d_{m\uparrow} d^{+}_{m\downarrow} d_{m\downarrow} + \sum_{m>m\prime,\sigma\sigma\prime} \boldsymbol{W} d^{+}_{m\sigma} d_{m\sigma} d^{+}_{m\prime\sigma\prime} d_{m\prime\sigma\prime} + \sum_{l>l'} \boldsymbol{2J} \mathbf{S}_{dl} \cdot \mathbf{S}_{dl'}$$

Intra-orbital Coulomb *Inter*-orbital Coulomb Hund rule's coupling

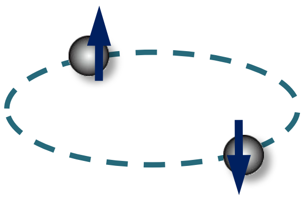
Ferro-magnetic Hund rule's coupling

→ Current fluctuation in do with low bias-voltage?

Fermi liquid（Renormalized perturbation theory）

Fano factor for $J \to -\infty$

For any intra-orbital Coulomb U with inter-orbital Coulomb $W \leqq U$



Ground state ➡ (2M-1)-fold spin multiplet

At Fermi liquid fixed point

- Residual Coulomb repulsion
- Residual Hund coupling

➡ Quasiparticle pair in current

- **Fano factor**

Mean field limit

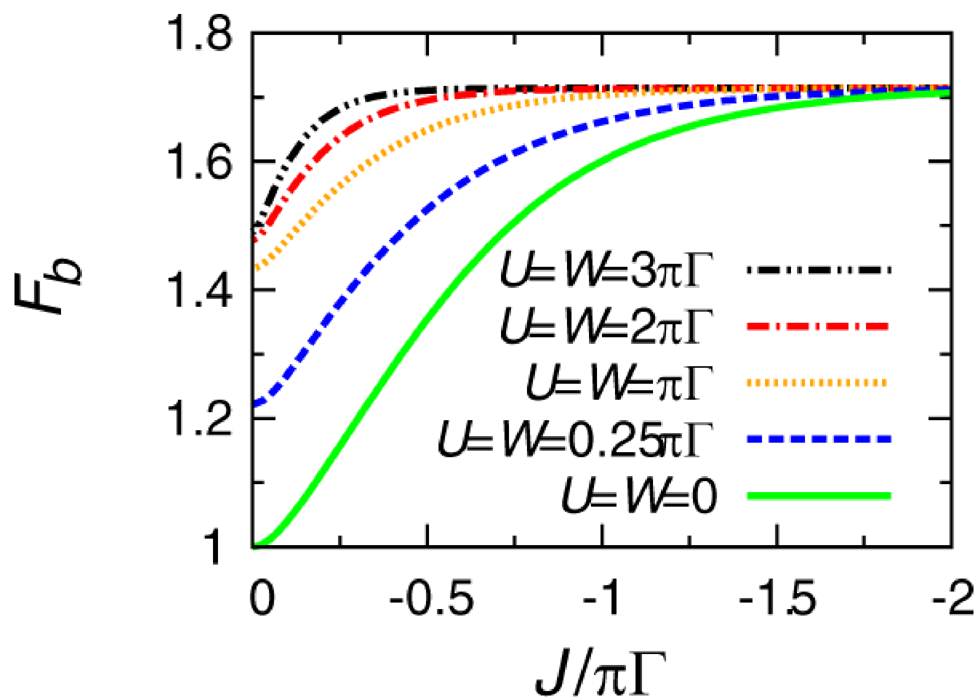
	M=2	M=3	M=4	M=5	$M \to \infty$
SU(2M) Kondo ($J = 0$)	3/2	7/5	4/3	9/7	1
$J \to -\infty$	**12/7**	**33/19**	**7/4**	**51/29**	**9/5**

Kondo correlation becomes more persistent.

Two-fold orbital case

Numerical renormalization group ➡ Fixed point parameter

Nishikawa, Crow, and Hewson, PRB **82**, 115123 (2010).



12/7

Same fixed point

Crossover around $-J \sim T_K$

"Hund rule's coupling enhances current fluctuation"

In my poster

Kondo effect and Hund coupling in quantum dot

⇒ Nonequilibrium current fluctuation

Full counting statistics

Renormalized perturbation theory

Exactly up to V^3

⇒ Cumulant of current distribution