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Spin-$\frac{1}{2}$ Kondo effect in an InAs nanowire quantum dot: Unitary limit, conductance scaling, and Zeeman splitting

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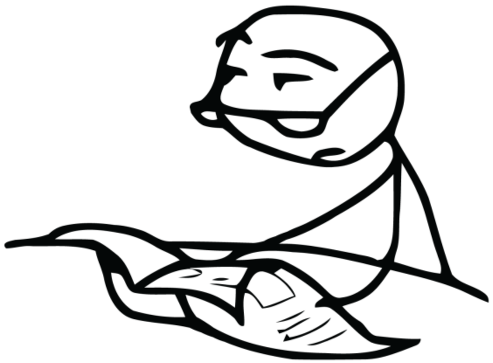

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NanoJC

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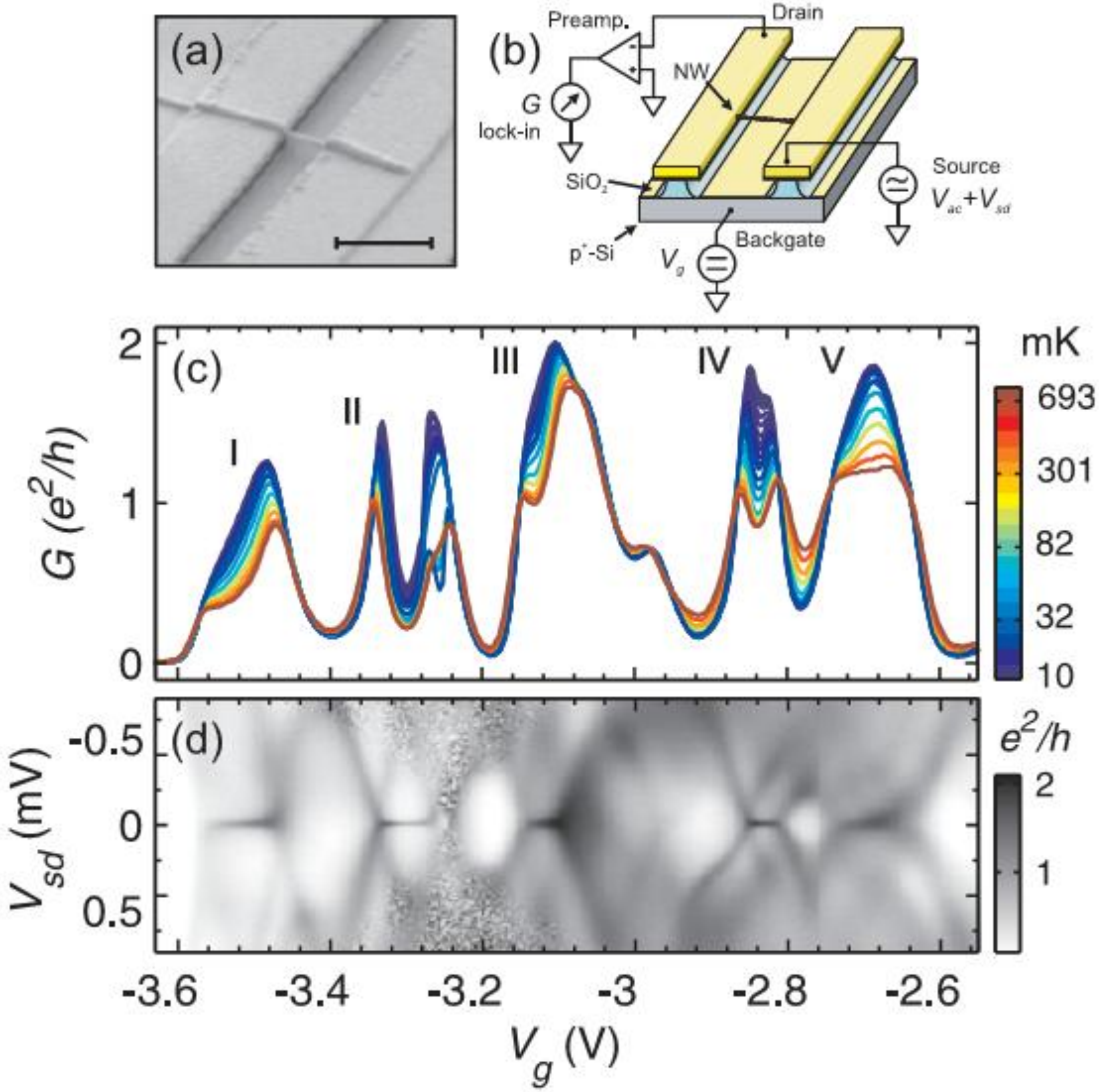
MŰEGYETEM 1782

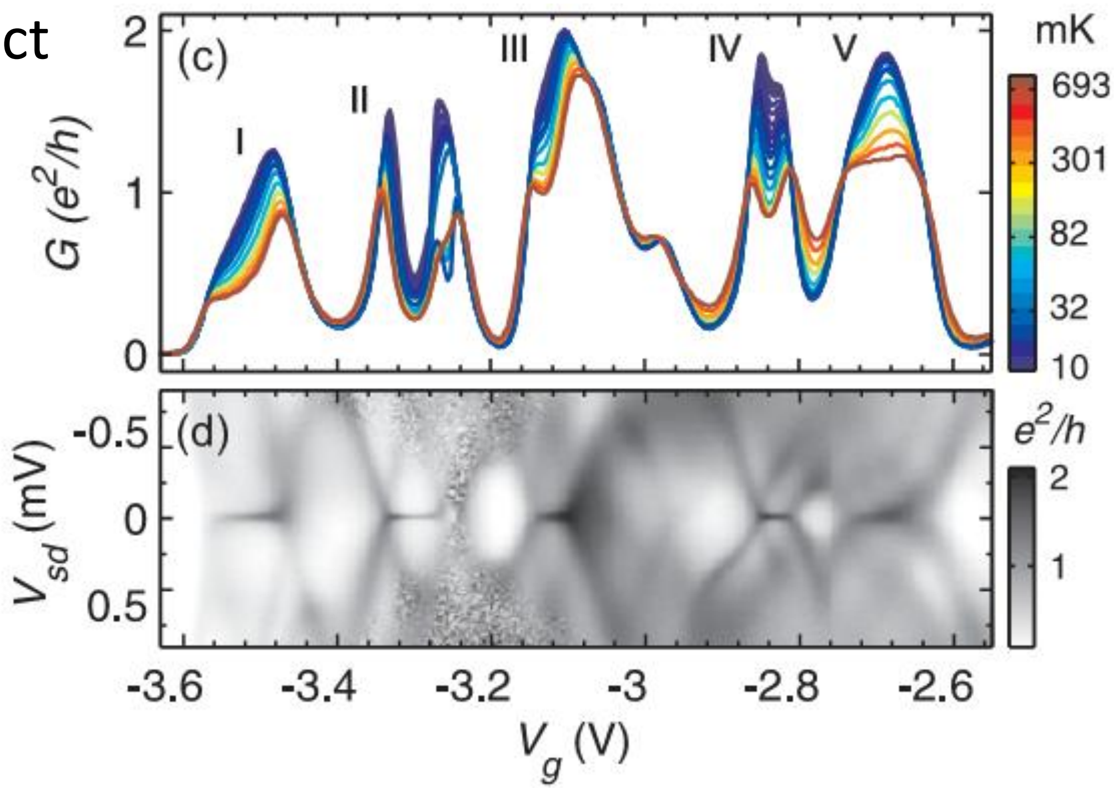
Outline

- Device fabrication
  - pure wurtzite InAs NWs
  - NWs suspended over grooves
- Kondo effect in the unitary limit
  - determination of T_K
- Conductance scaling
  - with temperature
  - with magnetic field
  - with bias



Kondo effect in the unitary limit

- Signatures of Kondo effect
  - Kondo valley
  - Supression of G by
    - bias
    - increasing temperature



Kondo effect in the unitary limit

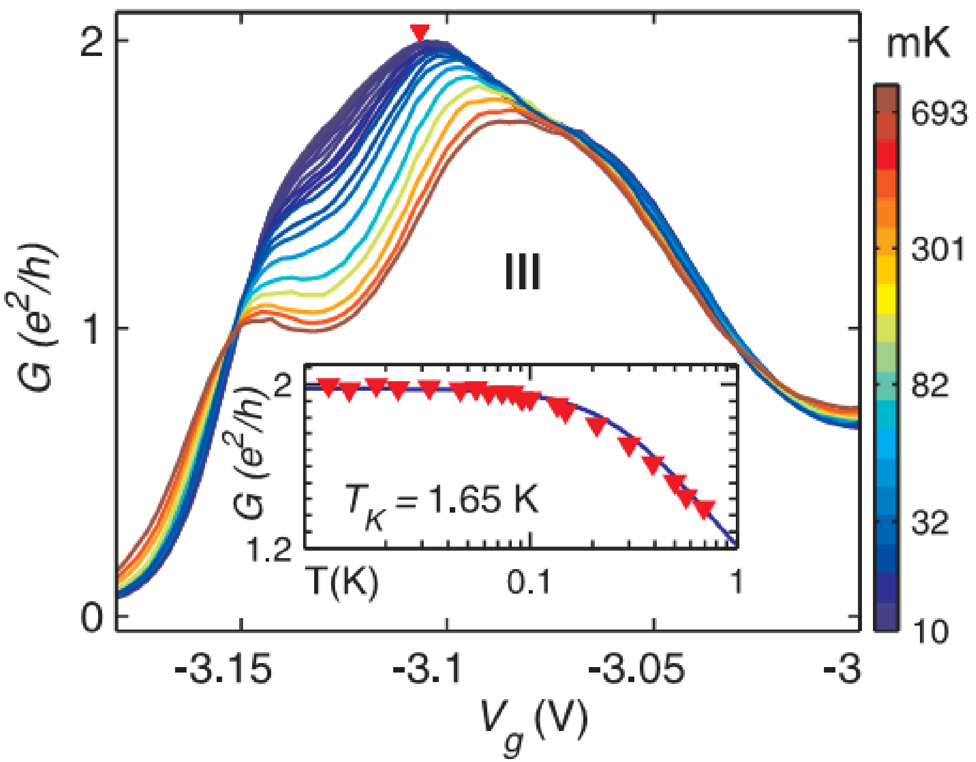
- Signatures of Kondo effect
  - Kondo valley
  - Supression of G by
    - bias
    - increasing temperature
- Kondo temperature

$$G(T) = G_0 \left[1 + (T/T'_K)^2\right]^{-s}$$

$$T'_K = T_K/(2^{1/s} - 1)^{1/2}$$

$$s = 0.22$$

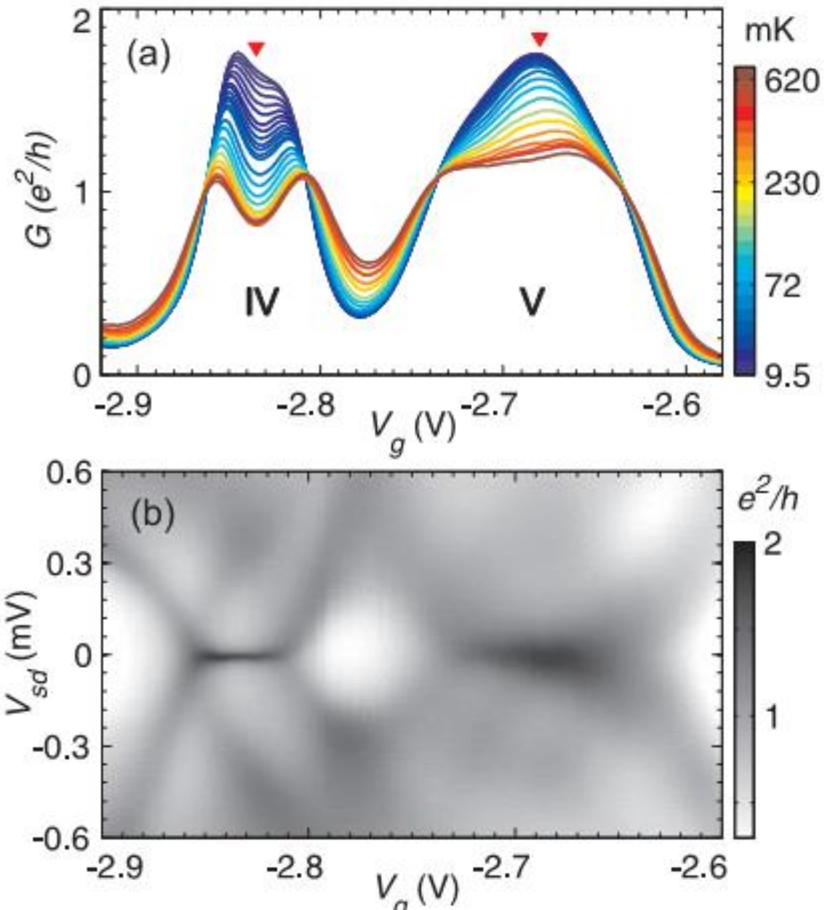
$$G(T_K) = G_0/2$$

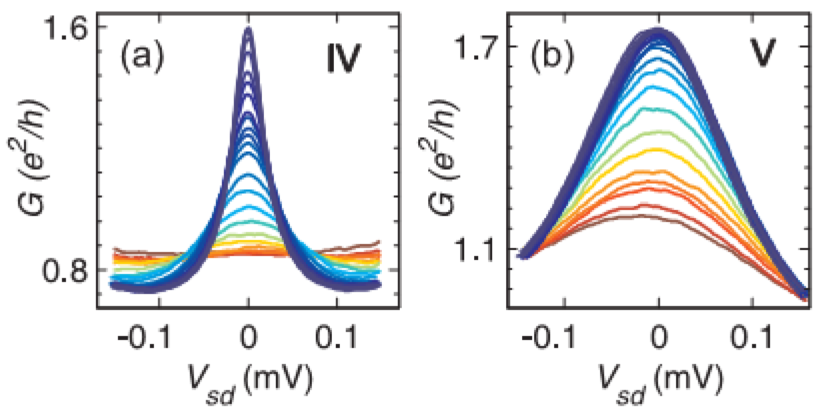


$T_K/T_{base} \approx 165$ → zero temperature limit

Kondo effect in the unitary limit

- Signatures of Kondo effect
  - Kondo valley
  - Supression of G by
    - bias
    - increasing temperature
- Kondo temperature
  - varying from valley to valley





Kondo effect in magnetic field

- Zeeman splitting of the ZBA

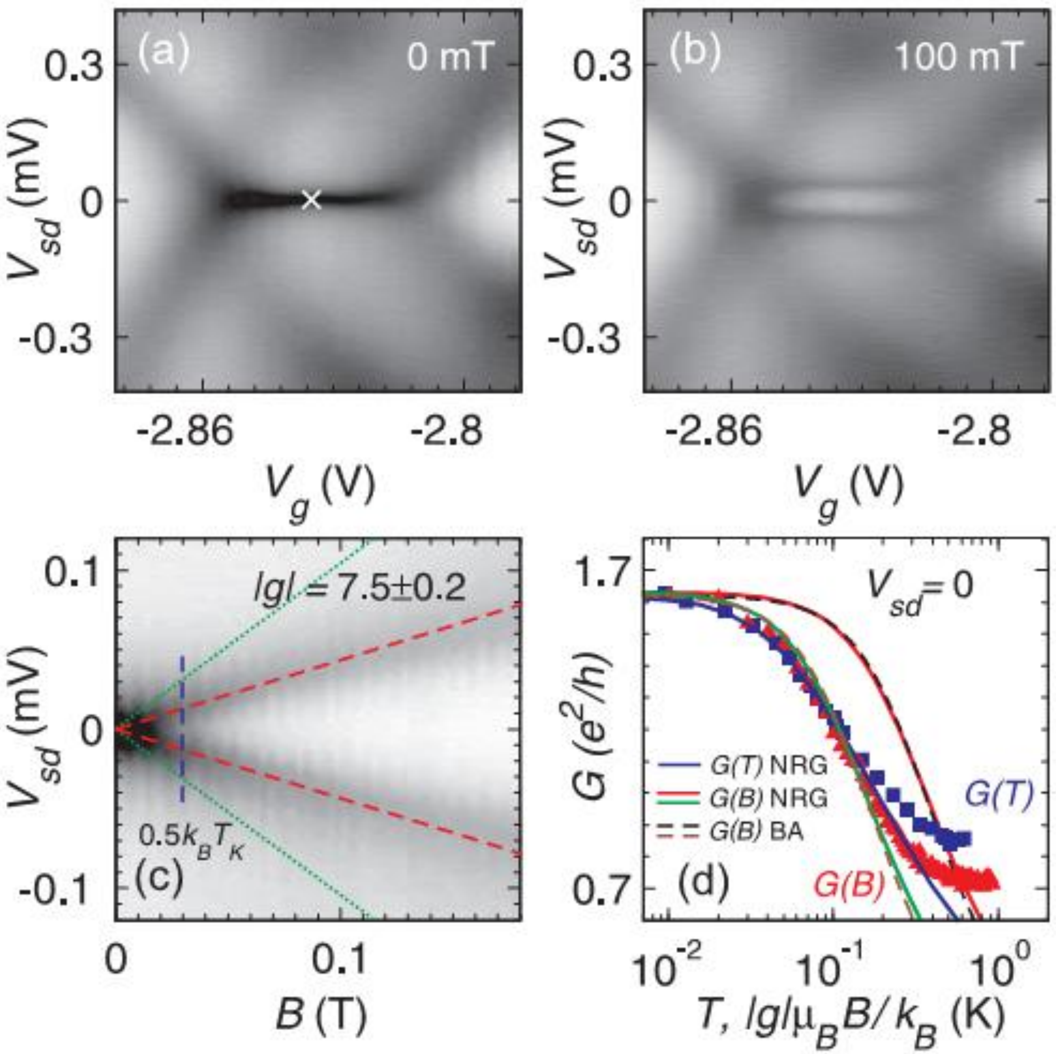
  $$\Delta = 2|g|\mu_B B$$

  – independent of V_G

- Supression of G by temperature and magnetic field

  – conflict between theory and experiment

$$T_B \equiv |g|\mu_B B / k_B$$



Universal conductance scaling

- Scaling with T and B
  - scaling function:

$$G(T) = G_0 \left[1 + (T/T'_K)^2\right]^{-s}$$

⇩

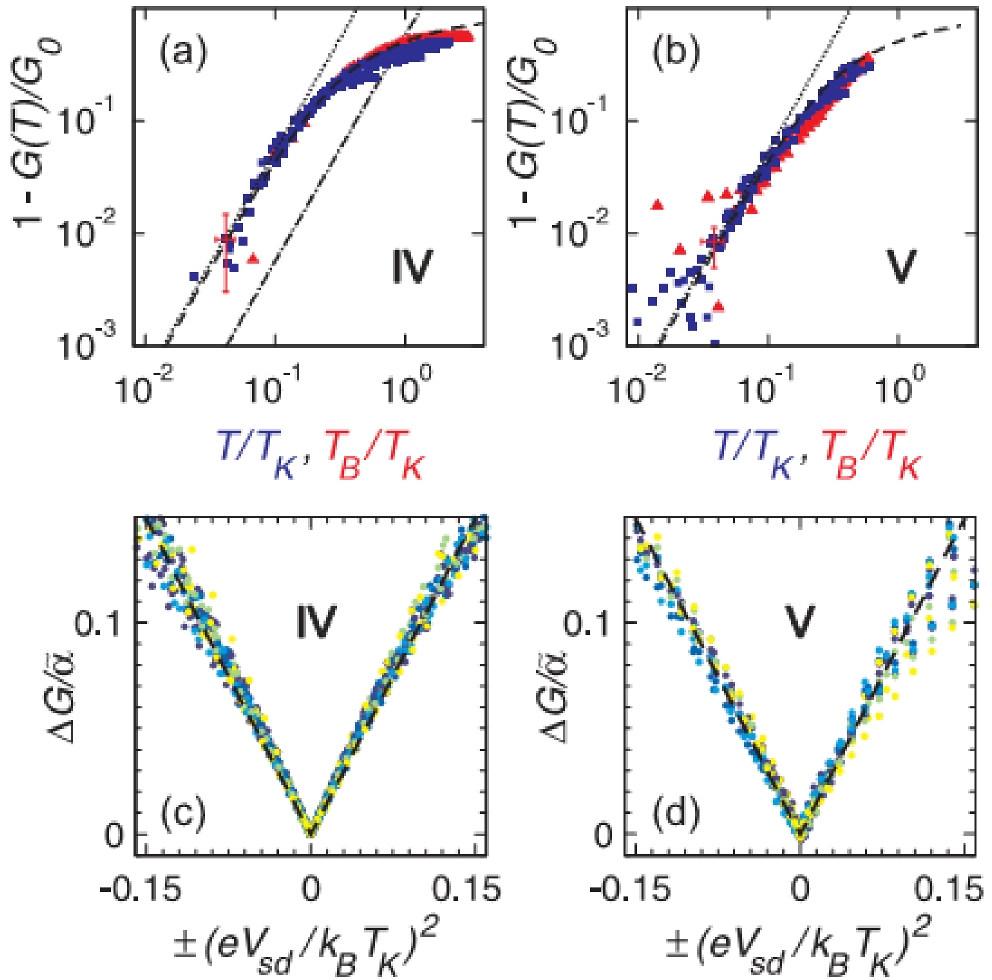
$$G/G_0 = f(T/T_K)$$

  - low energy limit:

$$G(T) = G_0[1 - c_T(T/T_K)^2],$$

$$G(B) = G_0[1 - c_B(|g|\mu_B B/k_B T_K)^2]$$

  - theory: $c_T = 5.38 \quad c_B = 0.55$
  - experiment: $c_B \approx c_T$

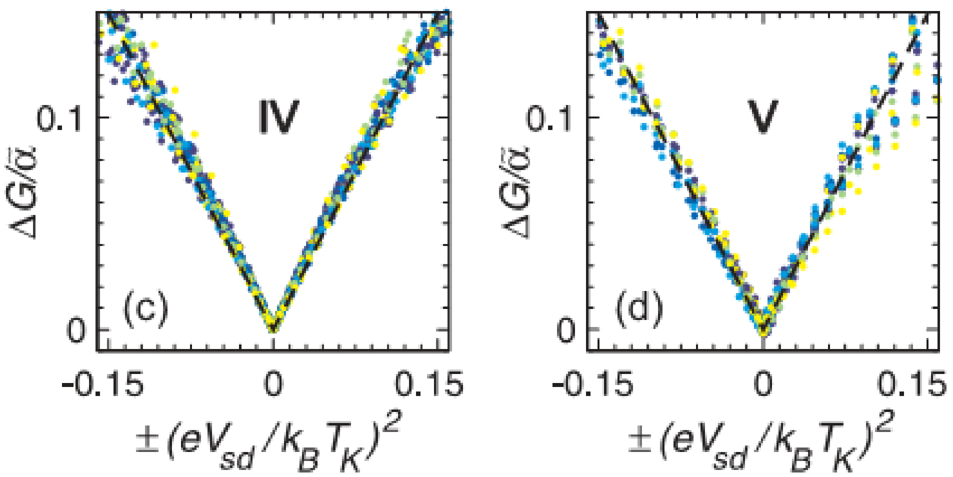


Universal conductance scaling

- Scaling with bias

$$G(T,V_{sd}) = G(T,0)\left[1 - \frac{c_T\alpha}{1+c_T\left(\frac{\gamma}{\alpha}-1\right)\left(\frac{T}{T_K}\right)^2}\left(\frac{eV_{sd}}{k_B T_K}\right)^2\right]$$

$$\Delta G/\tilde{\alpha} = (1 - G(T,V_{sd})/G(T,0))/\tilde{\alpha}$$



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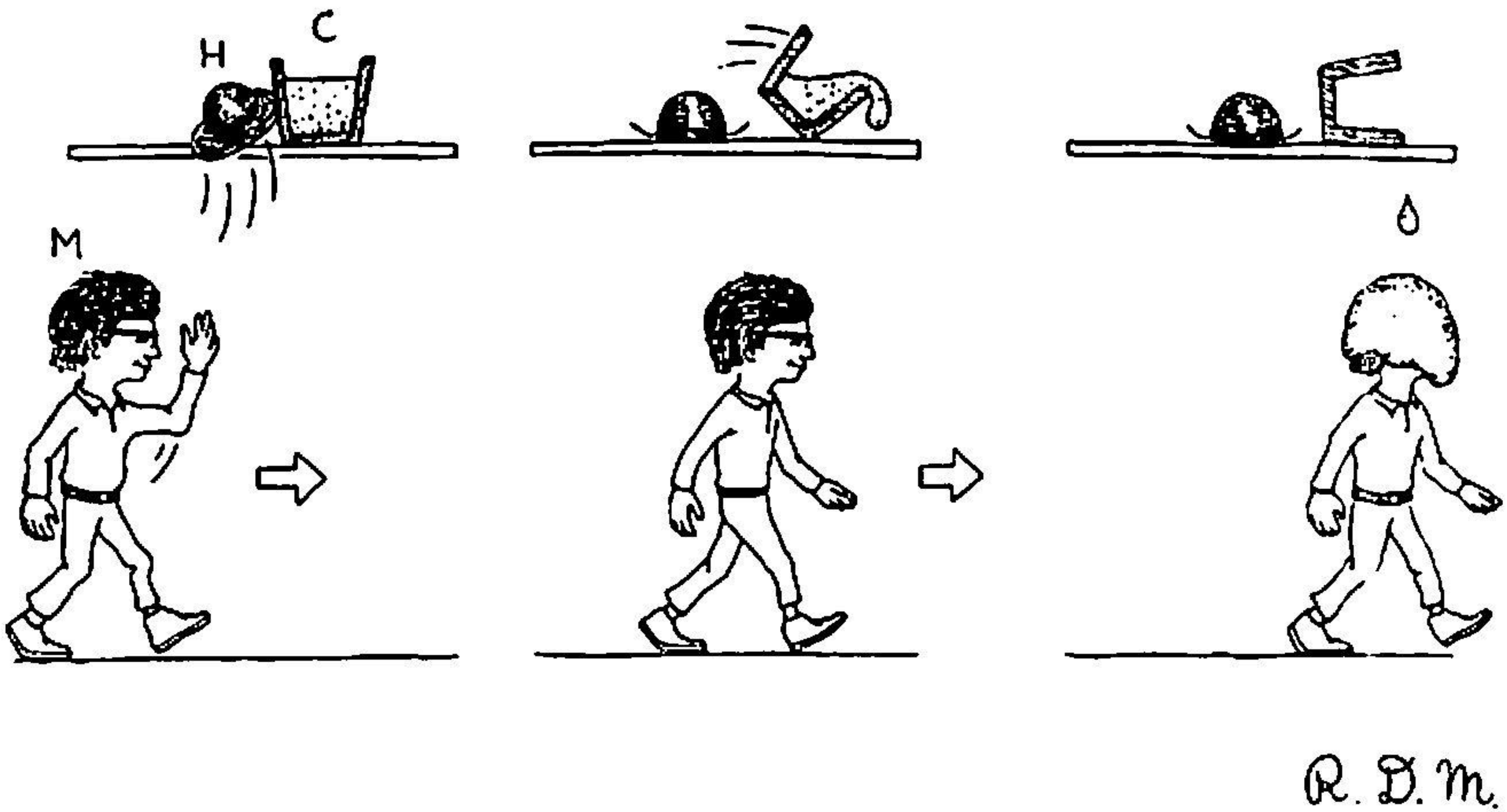


Fig. 18.2 ***Analogue of Electron-Impurity Spin Scattering in Kondo Problem***

NATURE | BREAKING NEWS

Quest for quirky quantum particles may have struck gold

Evidence for elusive Majorana fermions raises possibilities for quantum computers.

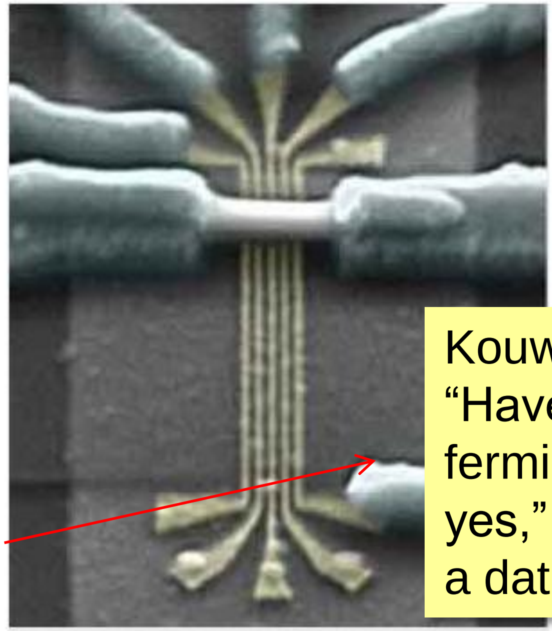
Eugenie Samuel Reich

28 February 2012

Getting into nanoscience pioneer Leo Kouwenhoven's talk at the American Physical Society's March meeting in Boston, Massachusetts, today was like trying to board a subway train at rush hour. The buzz in the corridor was that Kouwenhoven's group, based at the Delft University of Technology in the Netherlands, might have beaten several competing teams in solid-state physics — and the community of high-energy physicists — to a long-sought goal, the detection of Majorana fermions, mysterious quantum-mechanical particles that may have applications in quantum computing.

Kouwenhoven didn't disappoint. "Have we seen Majorana fermions? I'd say it's a cautious yes," he concluded at the end of a data-heavy presentation.

Quantum particles come in two types, fermions and bosons. Whereas bosons can be their own antiparticles, which means that they can annihilate each other in a flash of energy, fermions generally have



An electron micrograph of an indium antimonide nanowire (horizontal bar, centre) similar to that used to search for Majorana fermions.

DELFT UNIVERSITY OF TECHNOLOGY

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http://www.nature.com/news/quest-for-quirky-quantum-particles-may-have-struck-gold-1.10124