Electron Transport through Single Atoms and Molecules

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Acknowledgements

Experiment

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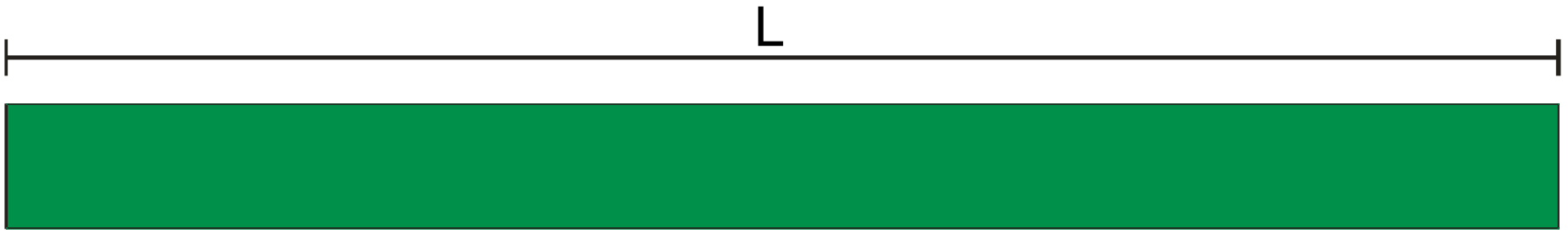
Theory

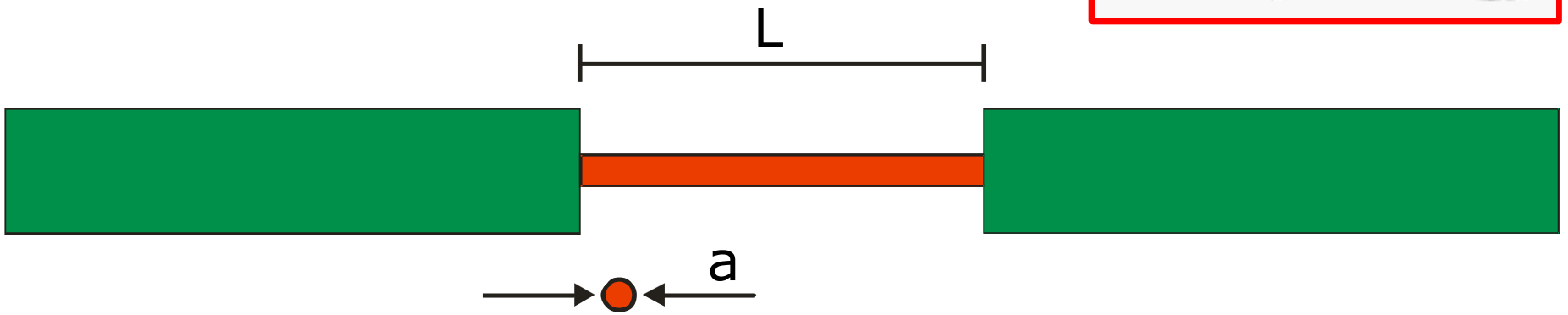
Th. Frederiksen, M. Brandbyge (Denmark)
K. Palotas, A. Garcia-Lekue, W.A. Hofer (United Kingdom)

Conductance

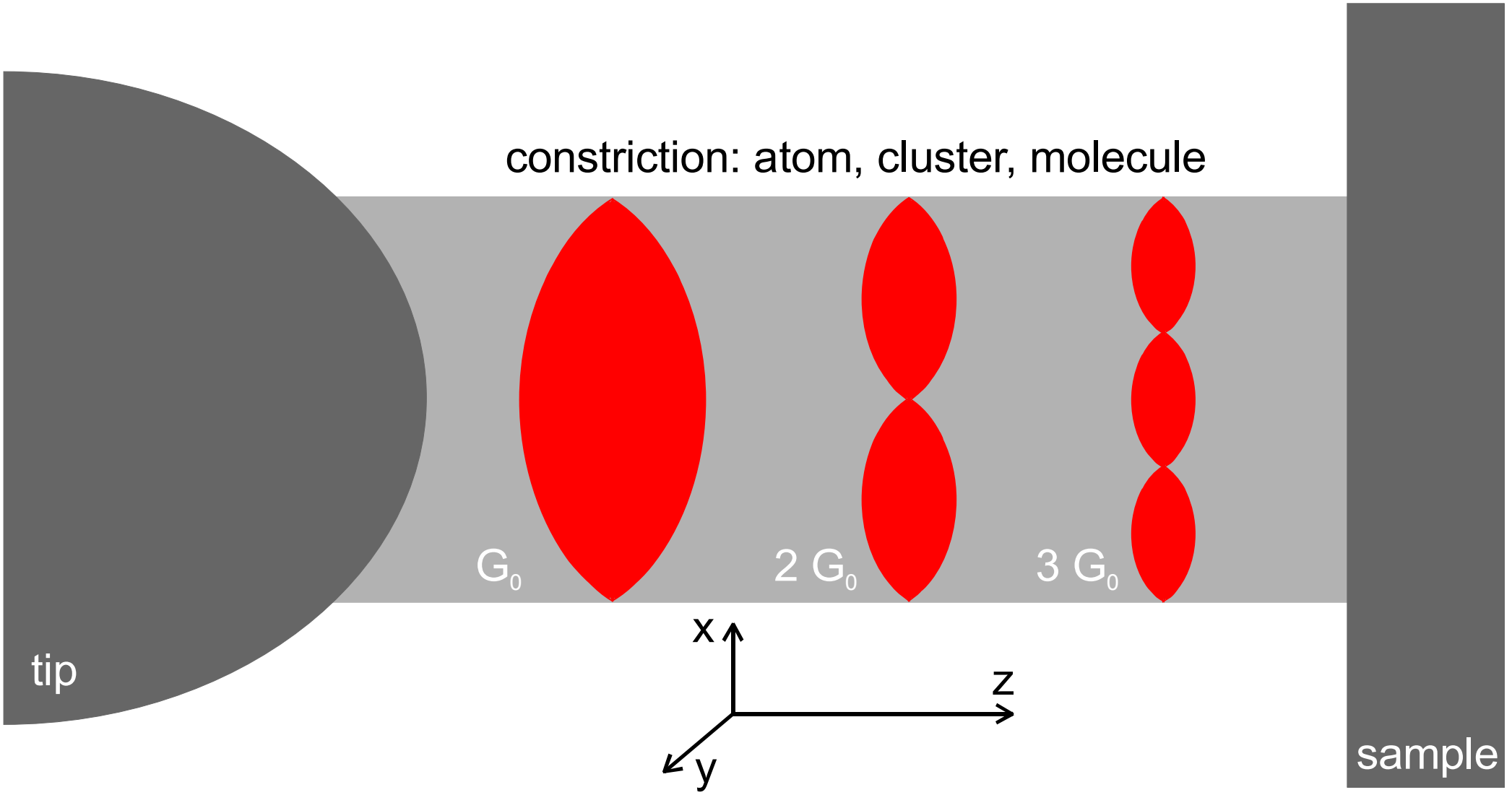


A

$$G \equiv \frac{I}{V} \equiv \sigma \frac{A}{L}$$

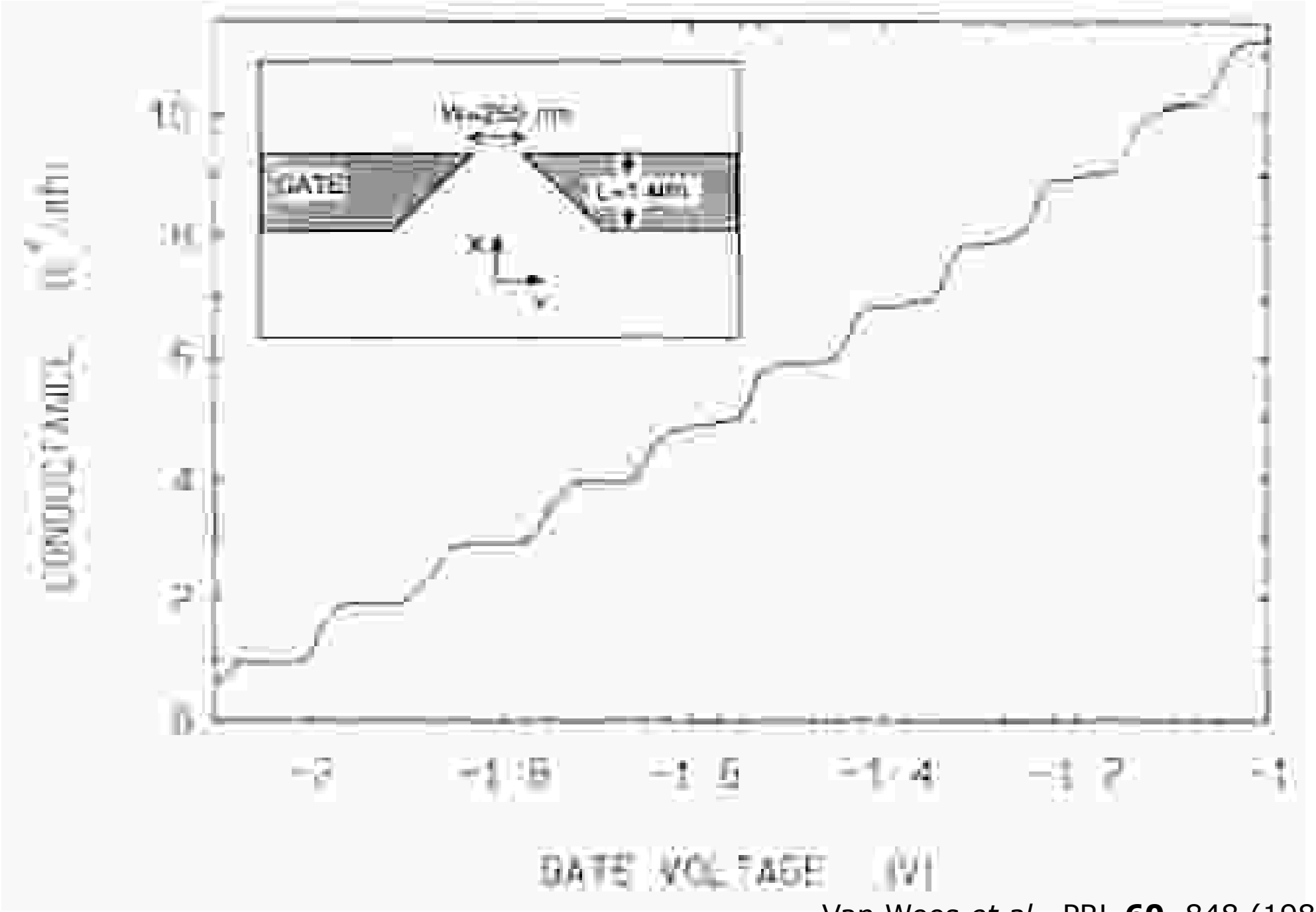


$$L < \ell, \quad a \ll \ell : \qquad G = \frac{2\,e^2}{h} T$$



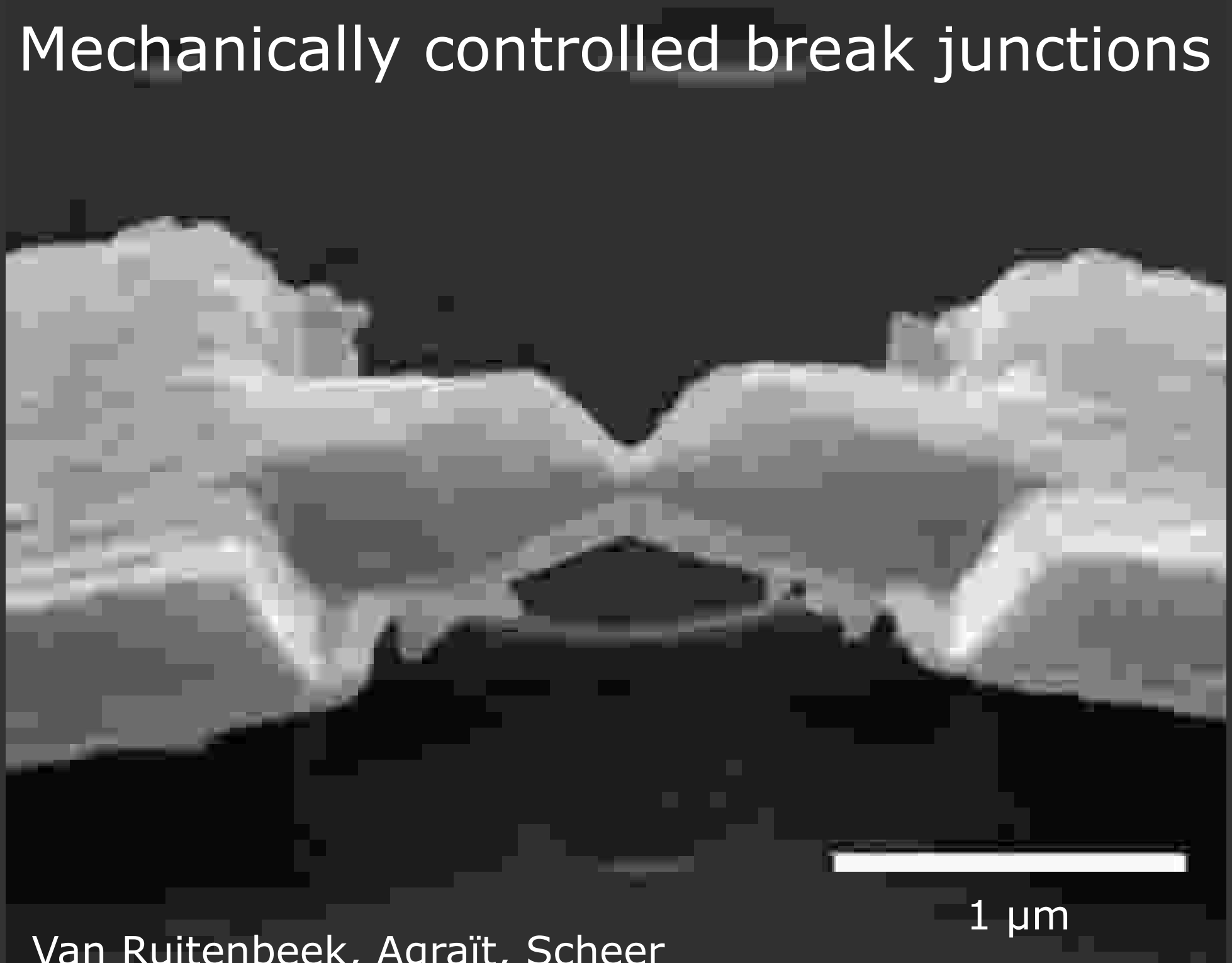
$$G \equiv \frac{2e^2}{h} \sum_{i=1}^{N} \tau_i$$

Conductance quantization in experiments



Van Wees *et al.*, PRL **60**, 848 (1988)

Mechanically controlled break junctions



Van Ruitenbeek, Agraït, Scheer

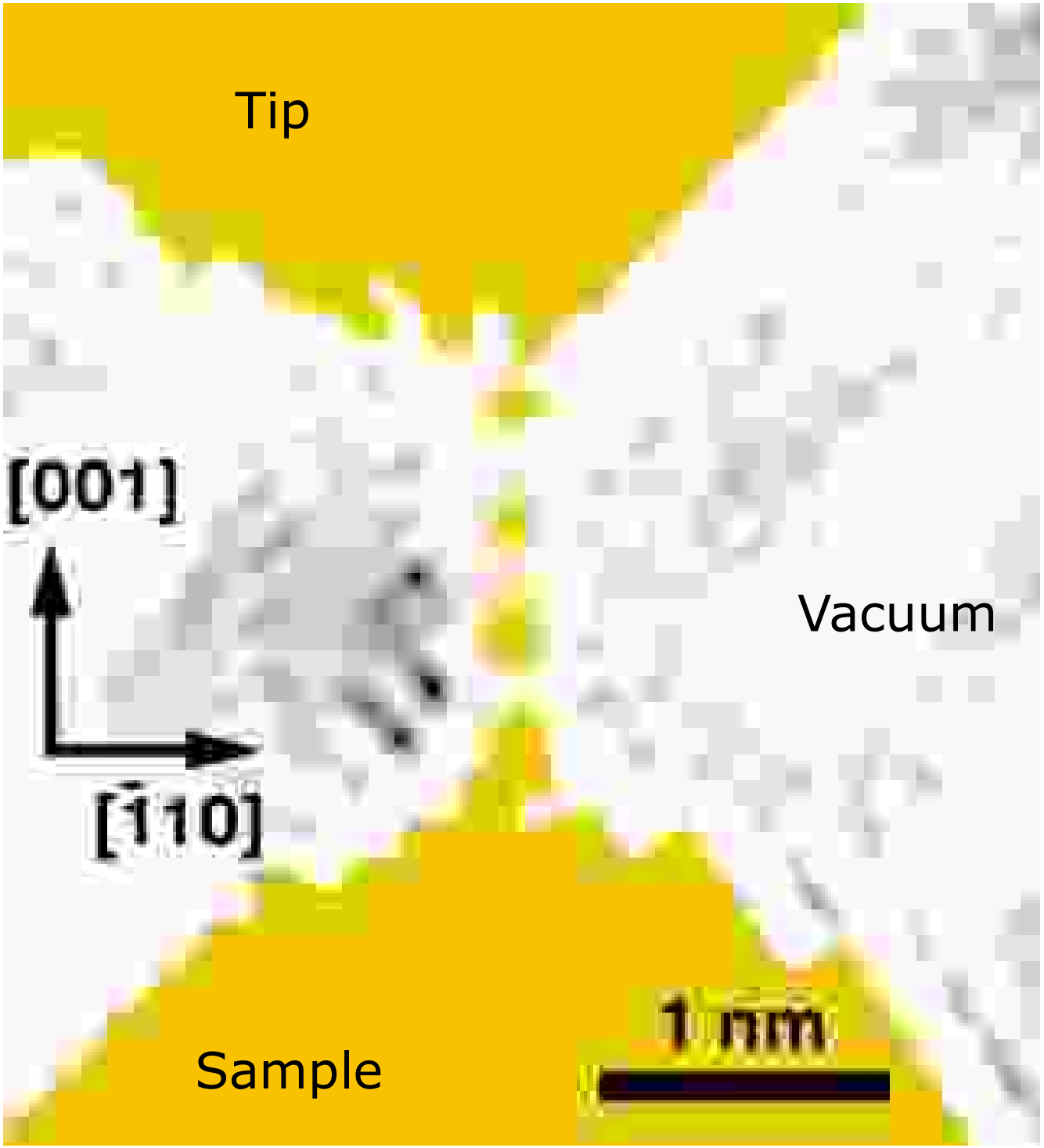
Number of conductance channels

=

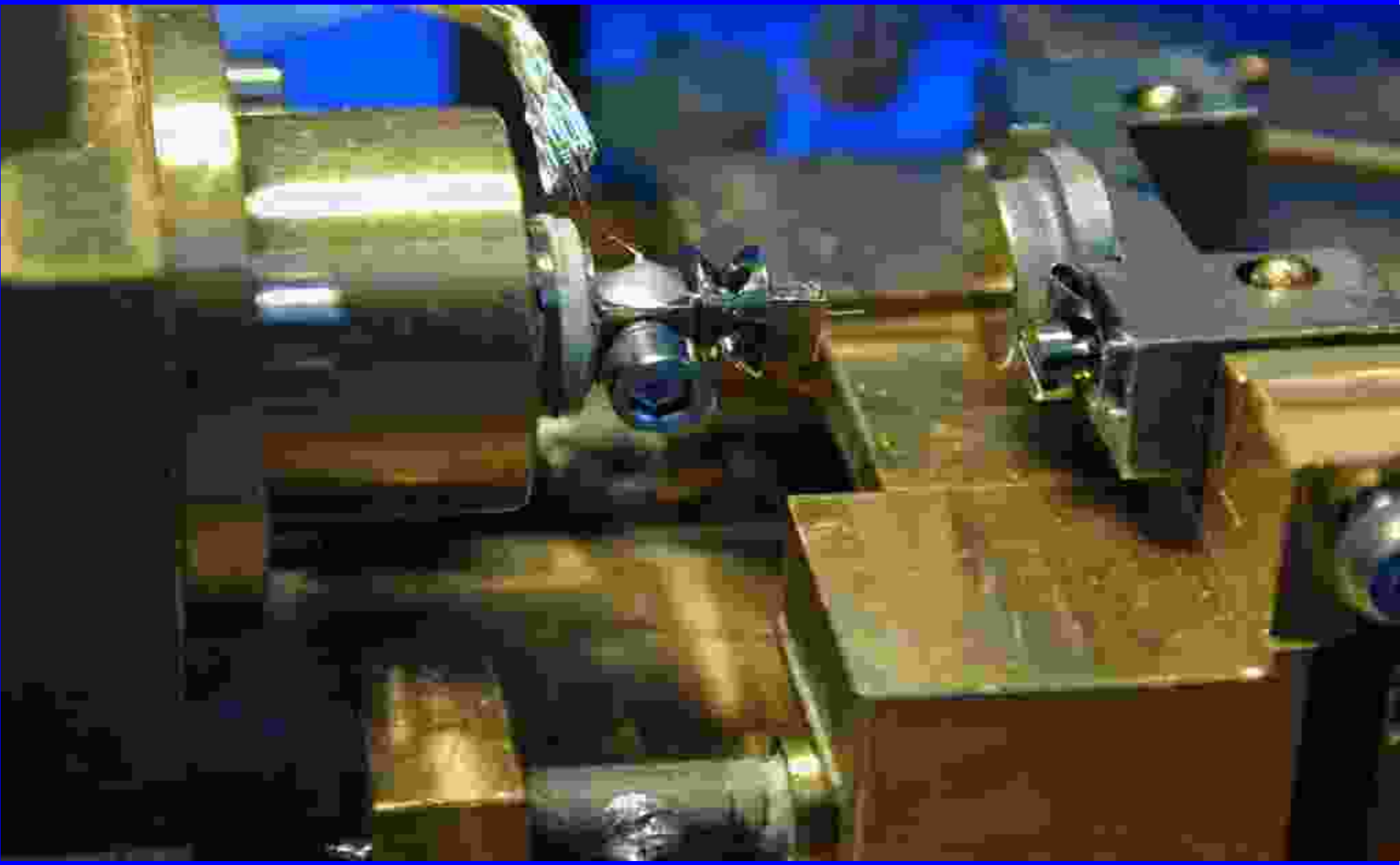
Number of valence orbitals

Scheer *et al.*, Nature **394**, 154 (1998)

Cuevas *et al.*, PRL **80**, 1066 (1998)



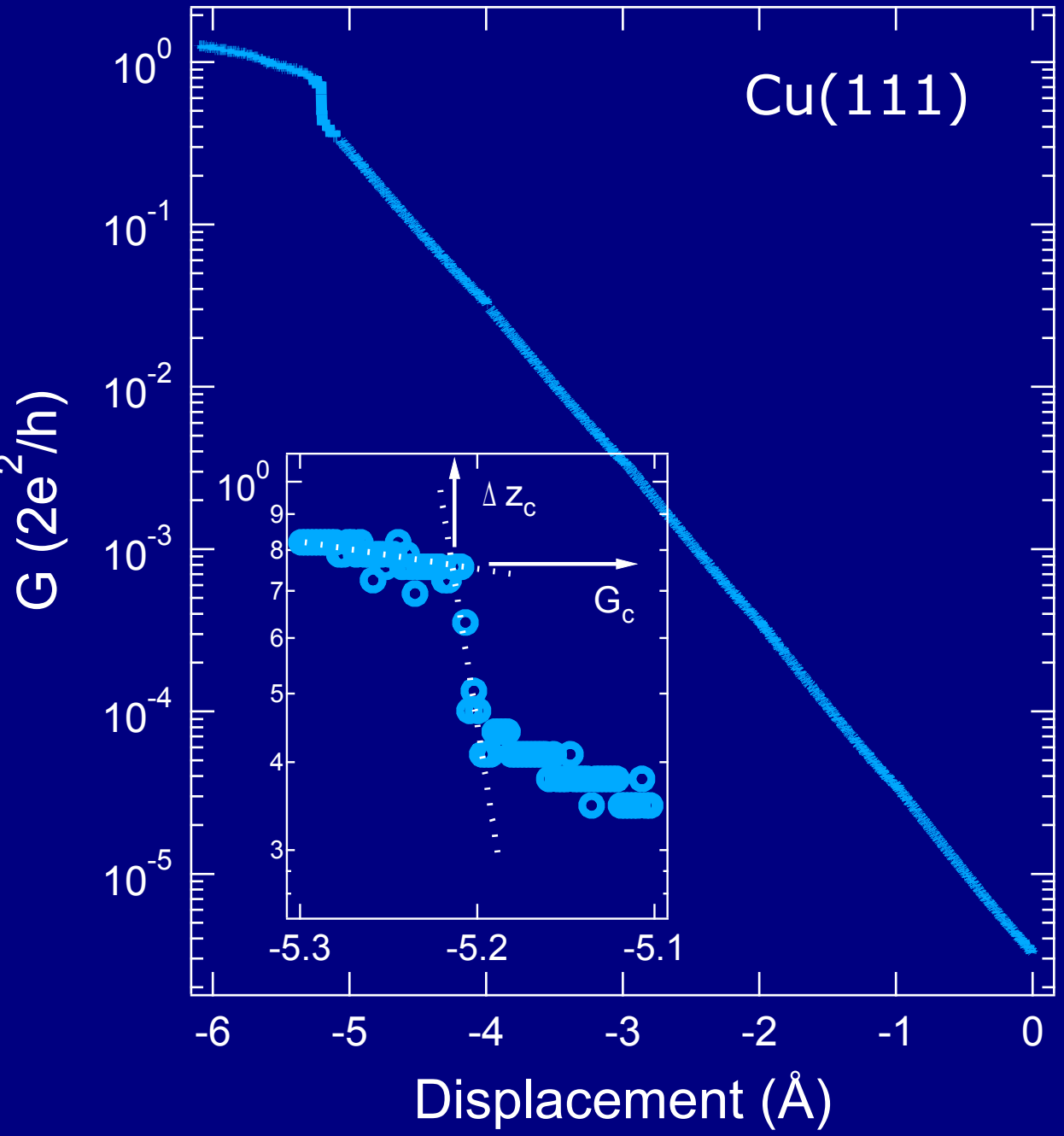
Ohnishi *et al*., Nature **395**, 780 (1998)

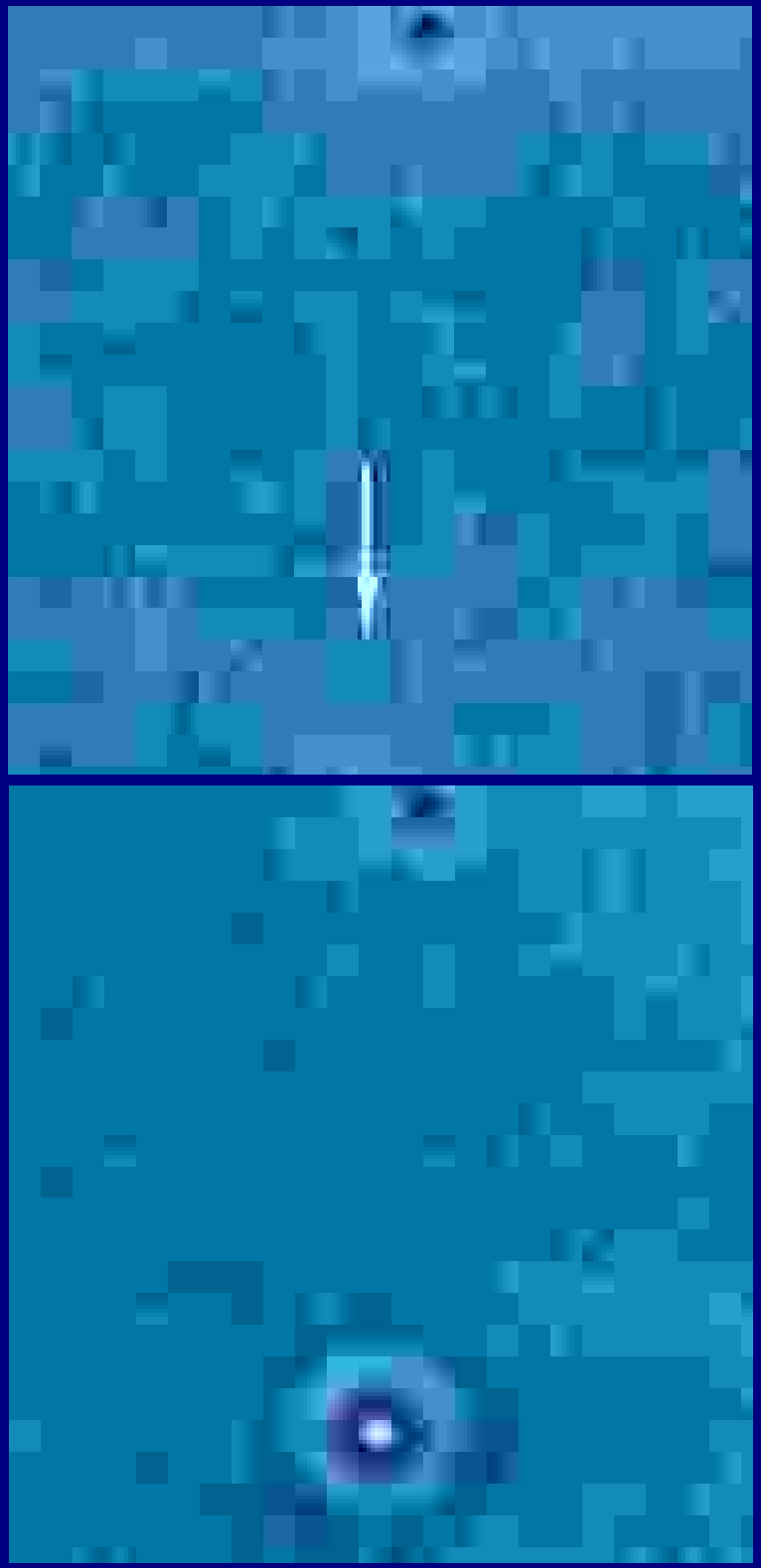


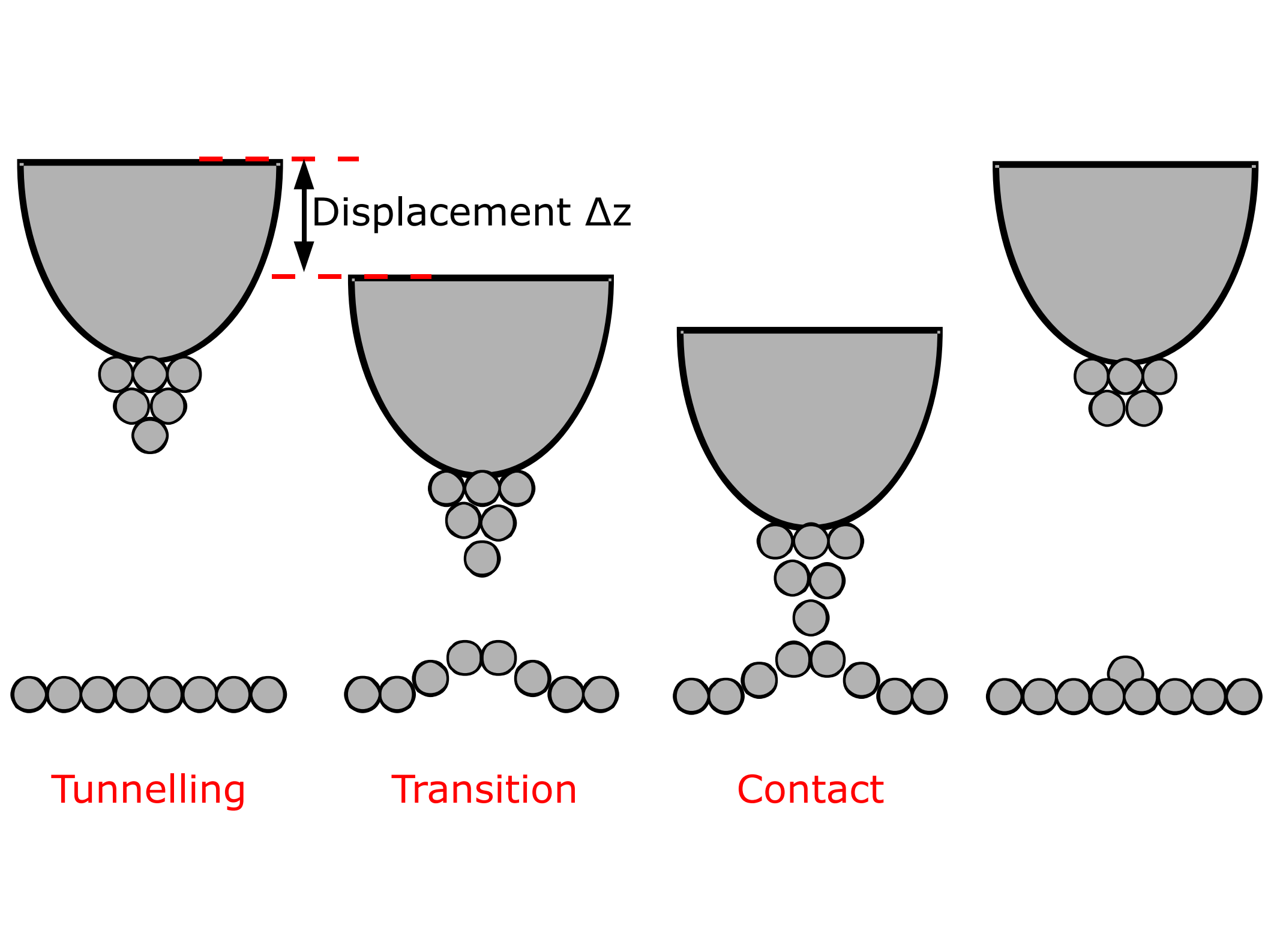
UHV, 7 K

Tip-surface contact

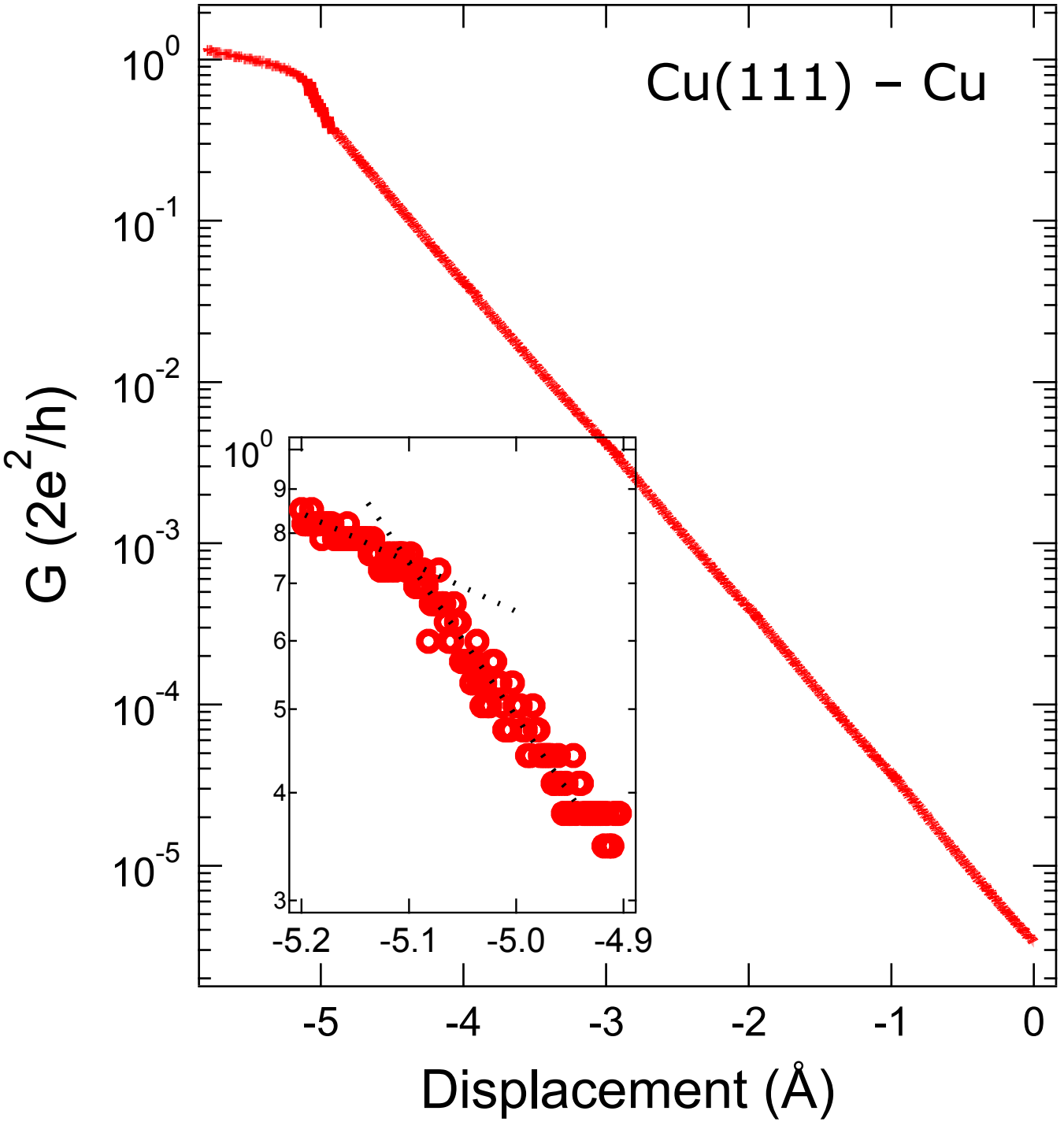
Limot, Kröger, Berndt, Garcia-Lekue, Hofer
PRL **94**, 126102 (2005)

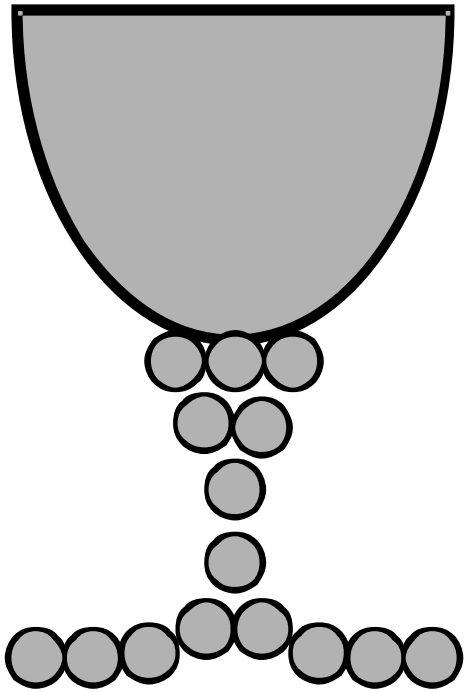





Displacement Δz
Tunnelling
Transition
Contact

Tip-adatom contact

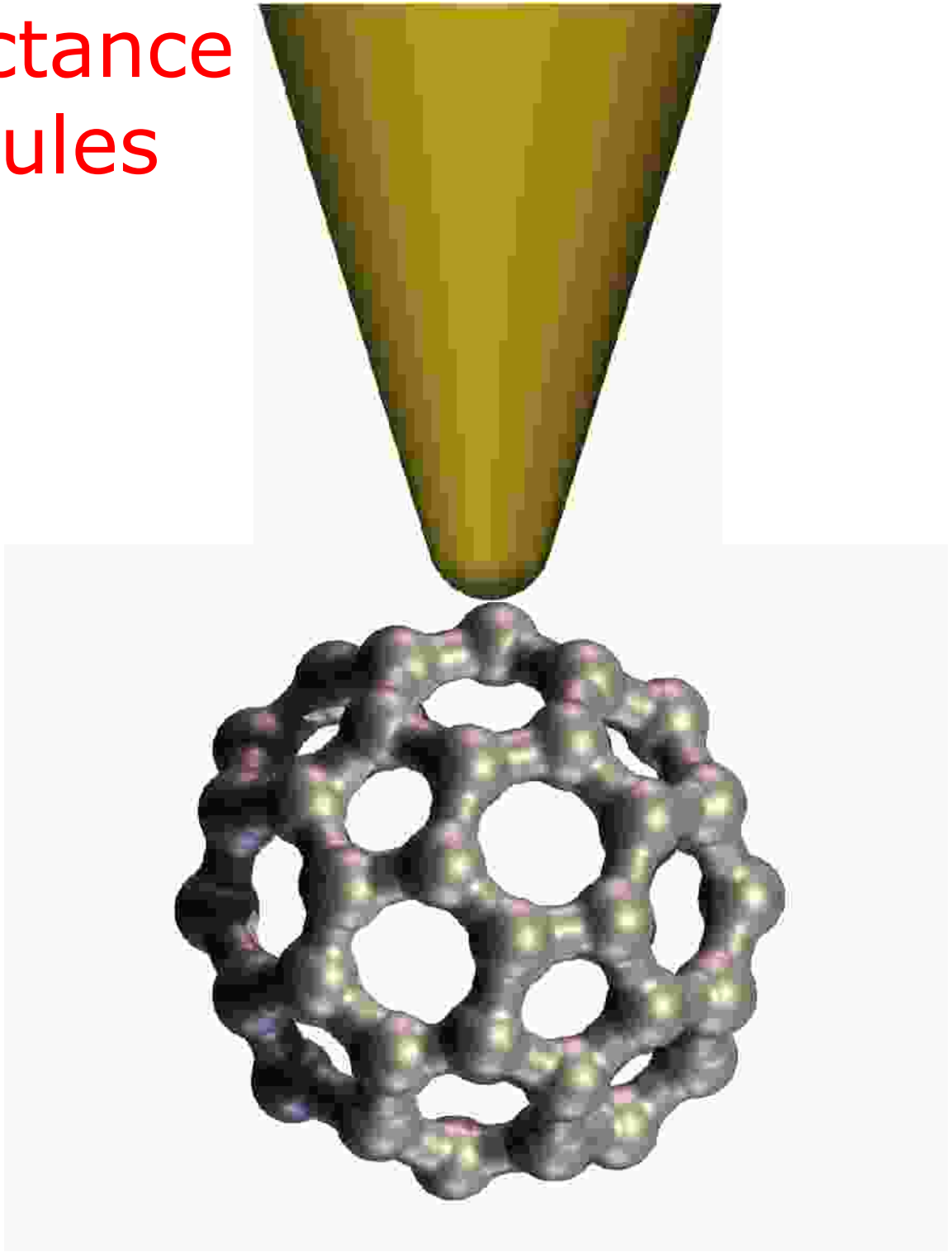


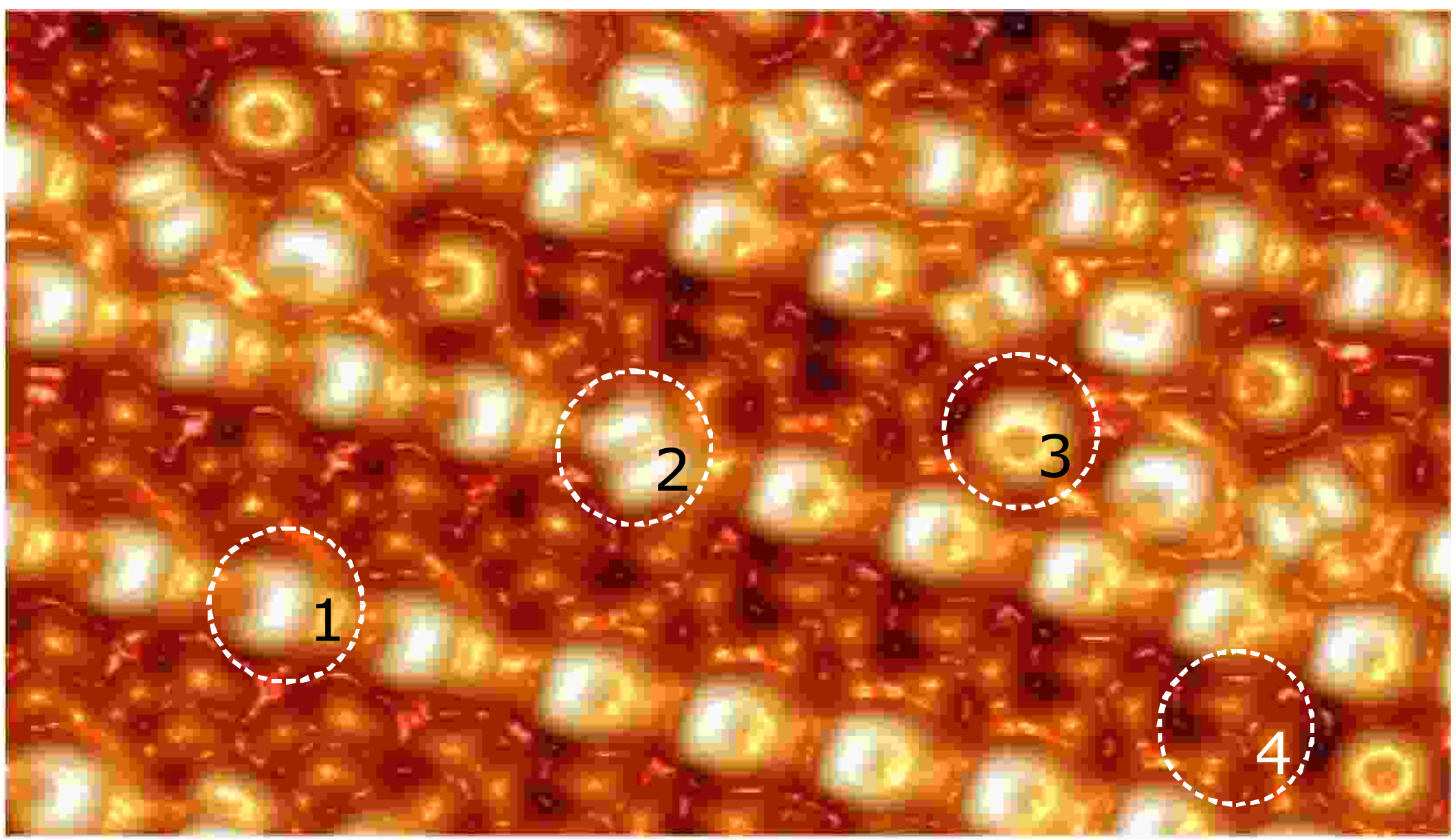


Ag(111)
PRL **94**, 126102 (2005)

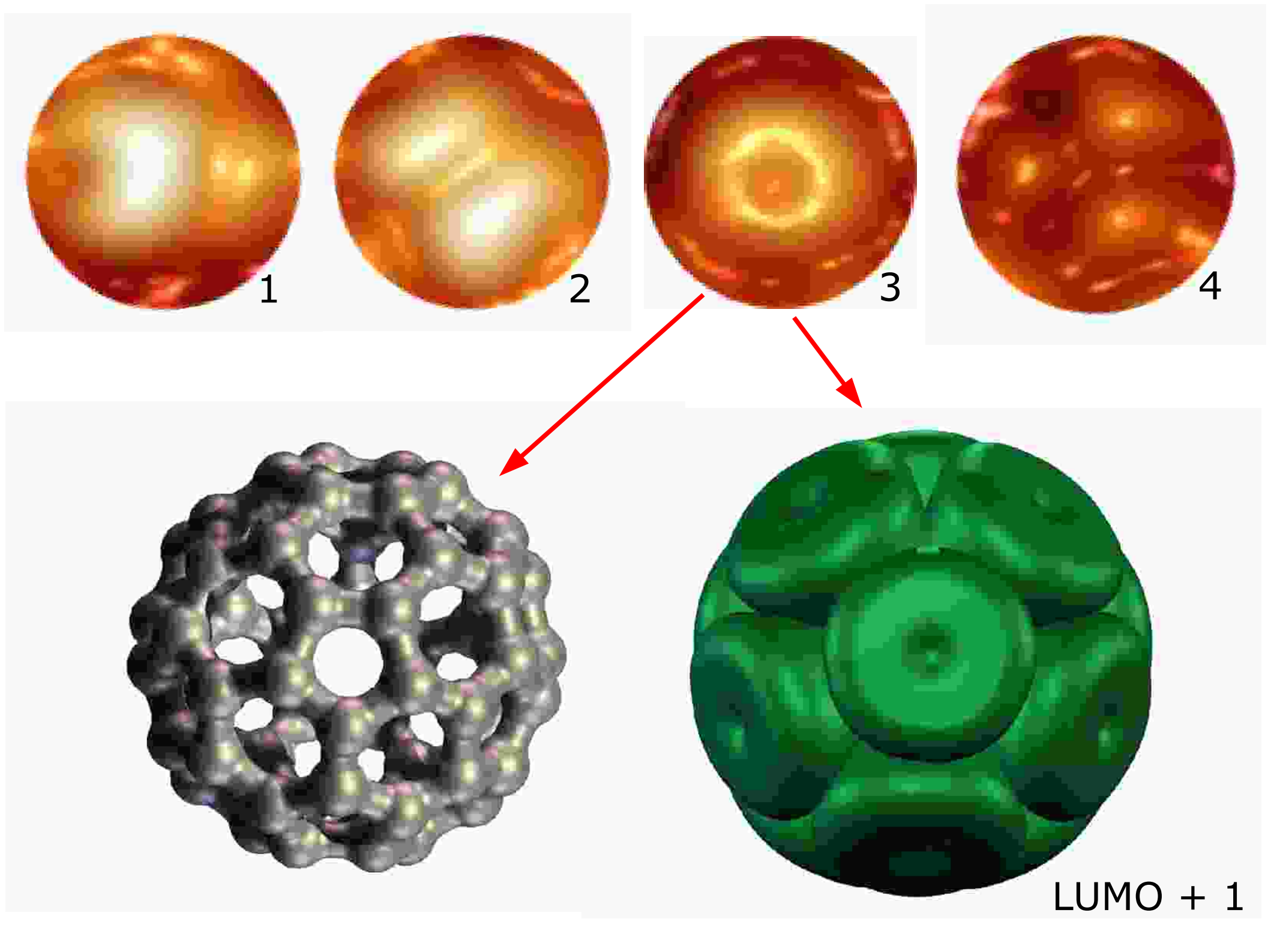
Au(111)
New J. Phys. **9**, 153 (2007)

Probing the conductance of individual molecules

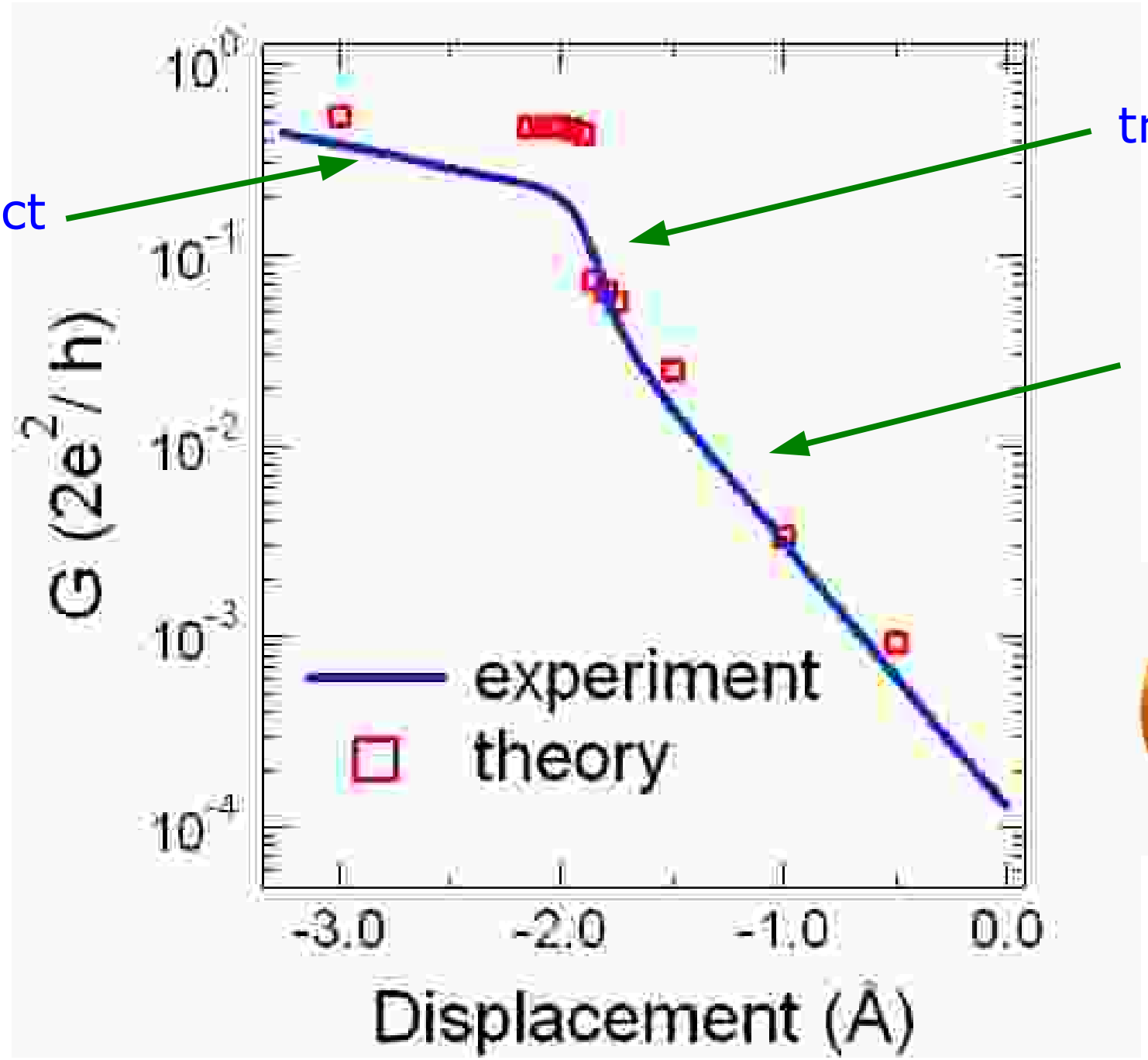




Cu(100) – C_{60}: 4 molecule orientations

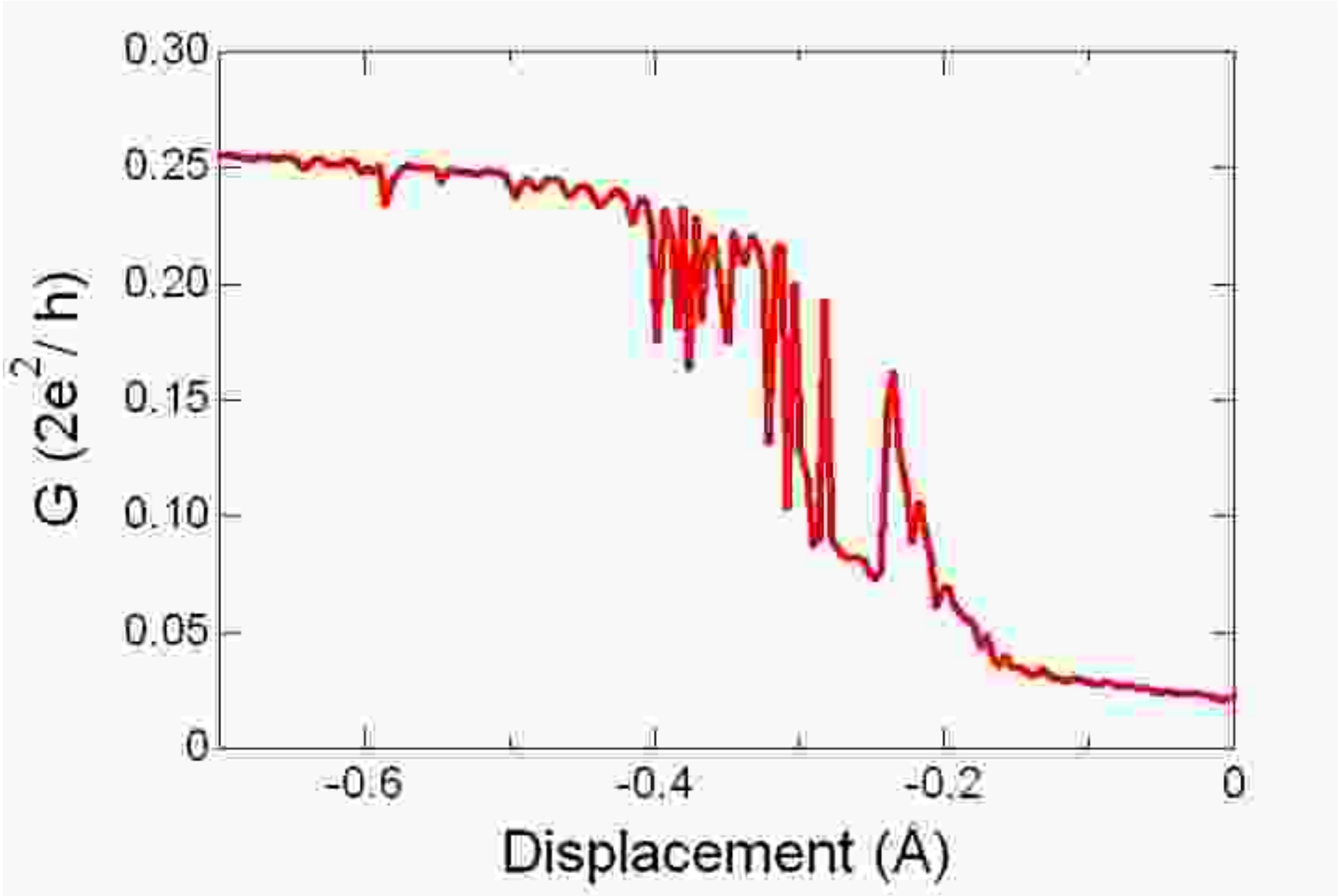

1
2
3
4
LUMO + 1

Tip – Molecule Contact

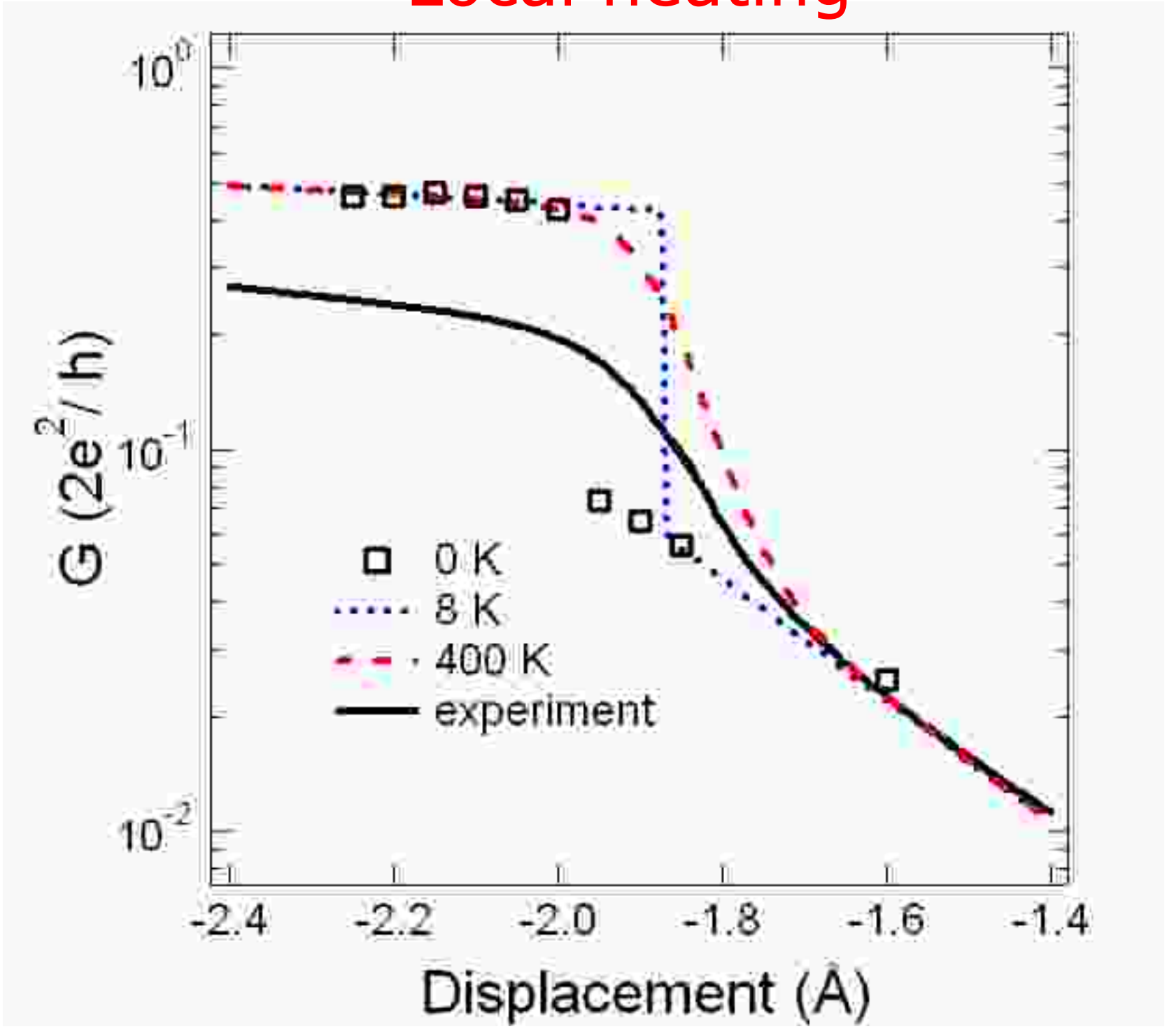


Néel, Kröger, Limot, Frederiksen, Brandbyge, Berndt, PRL **98**, 065502 (2007)

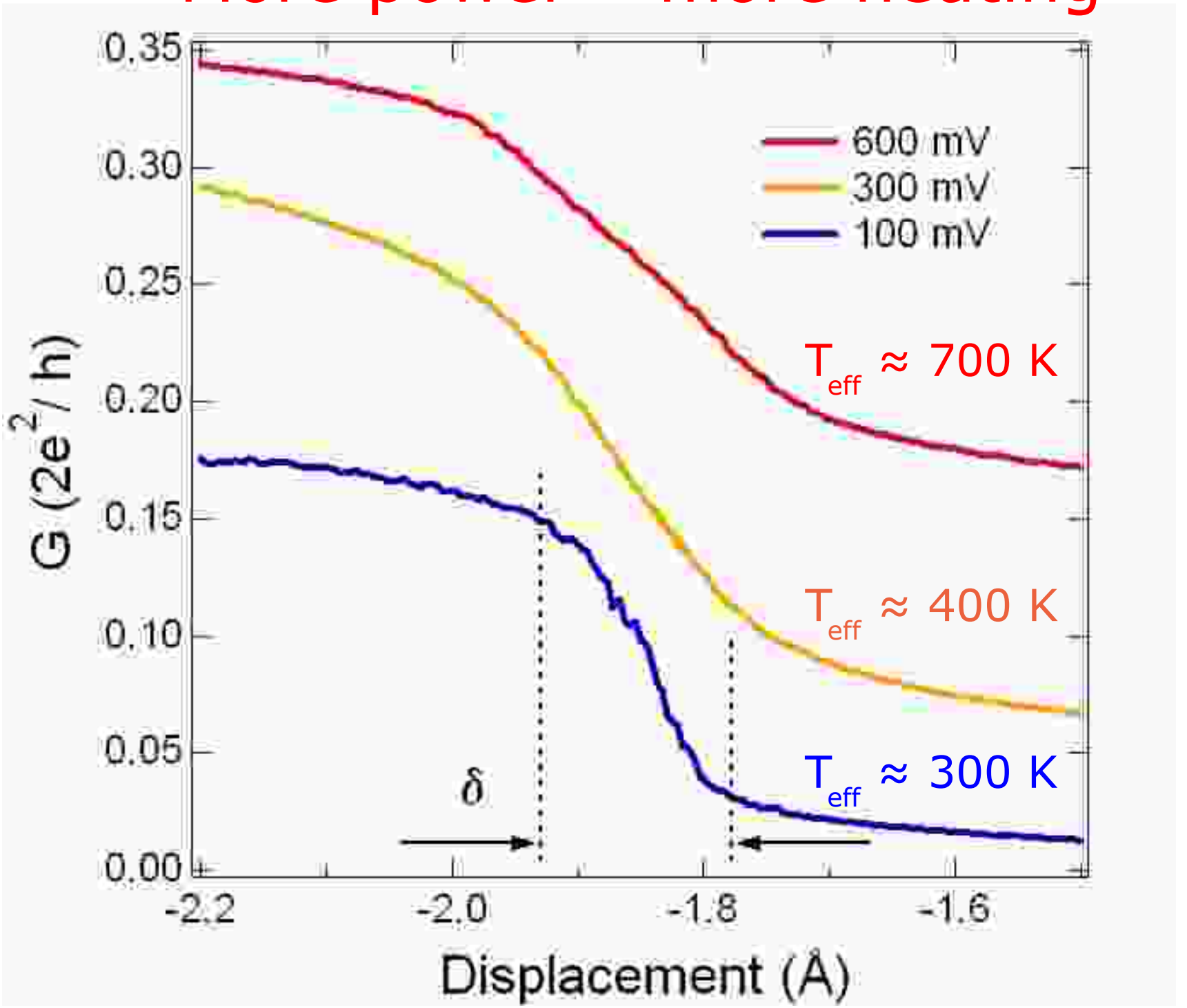
Fluctuations in transition regime



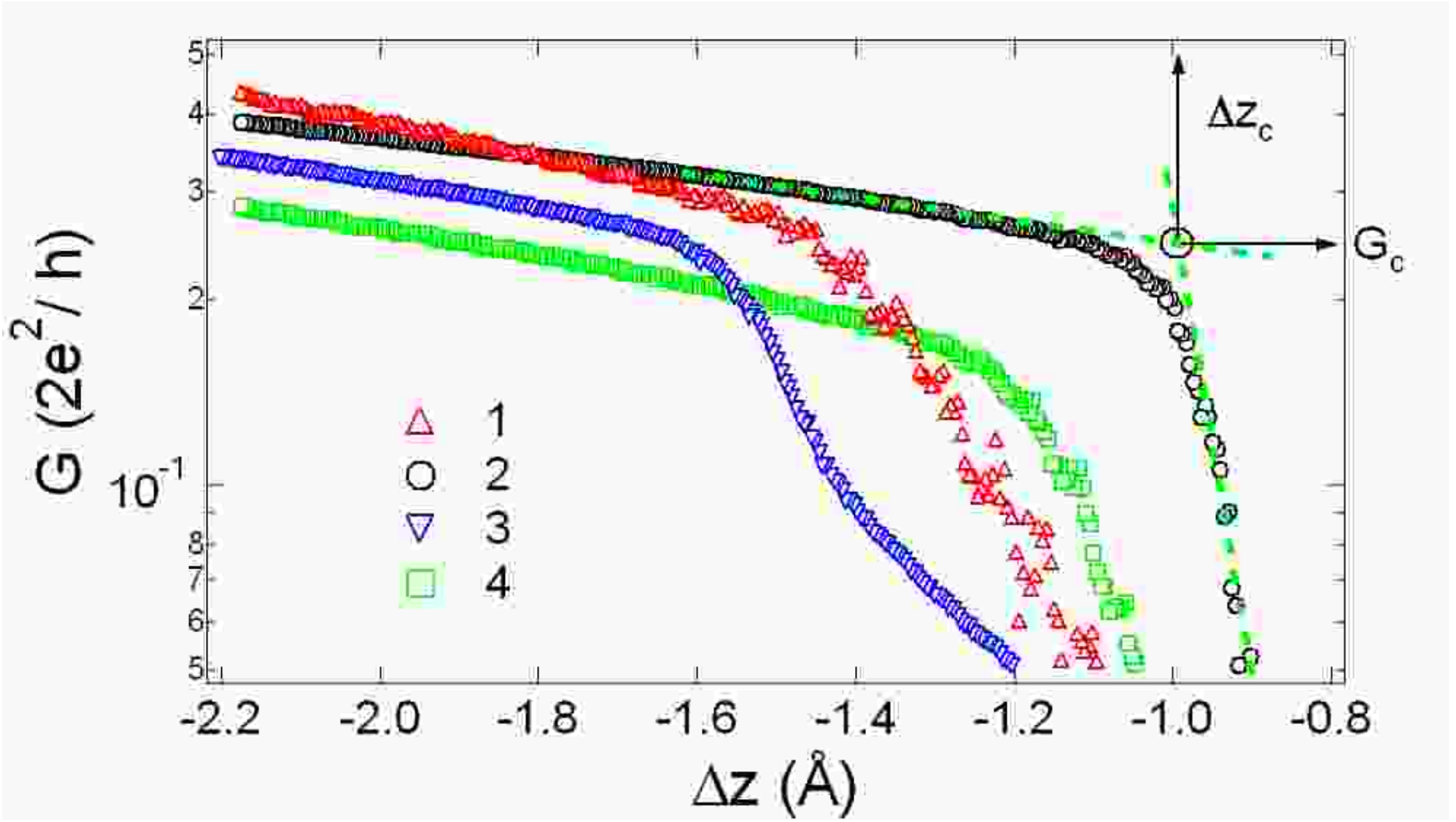
Local heating



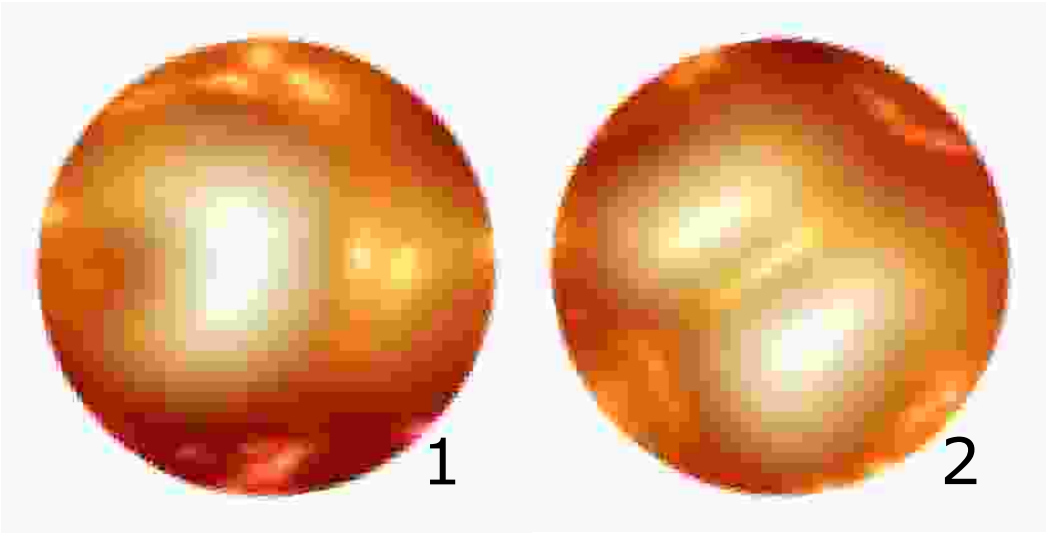
More power – more heating



Orientation-dependent conductance

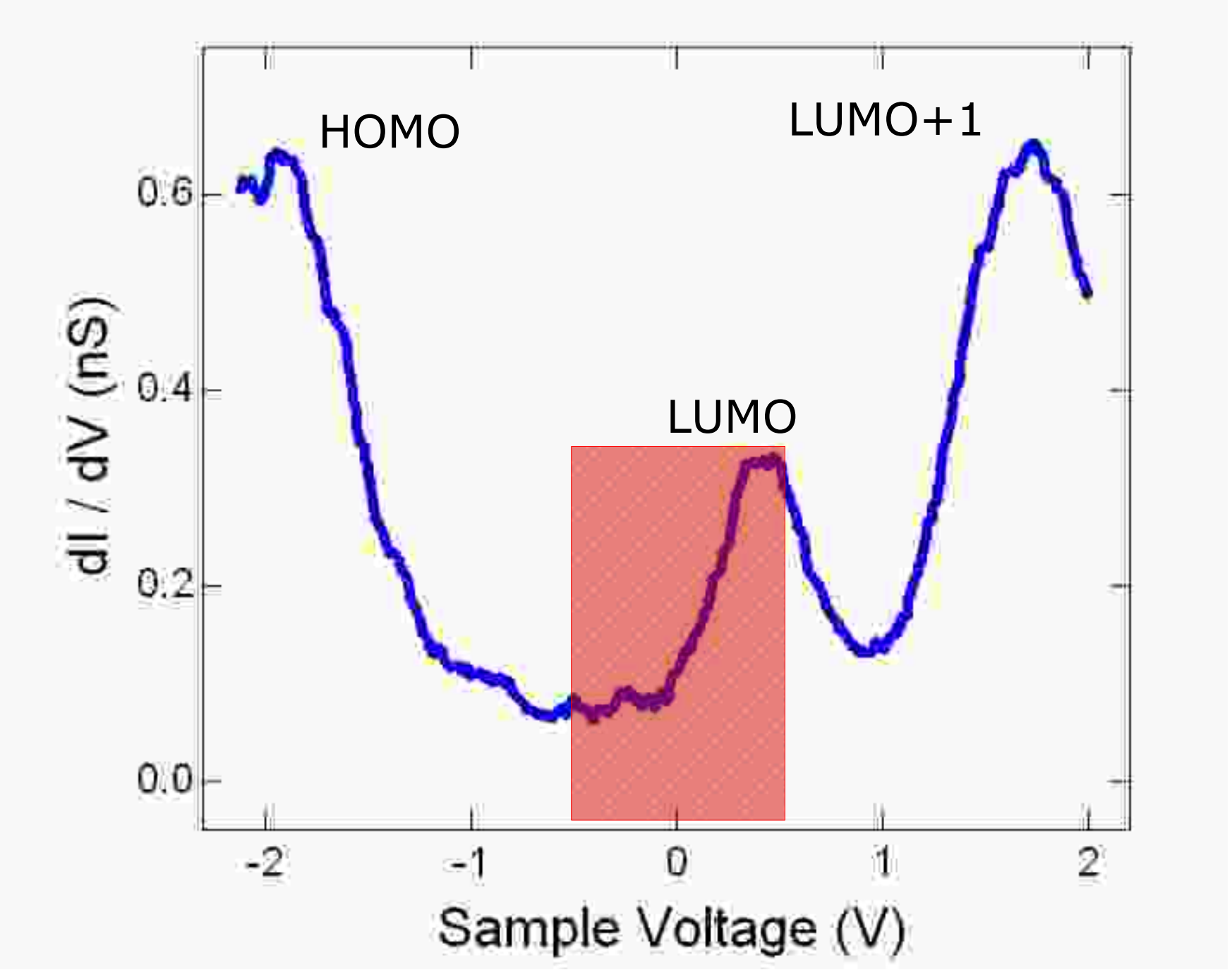


Néel, Kröger, Limot, Berndt, Nano Letters, published online

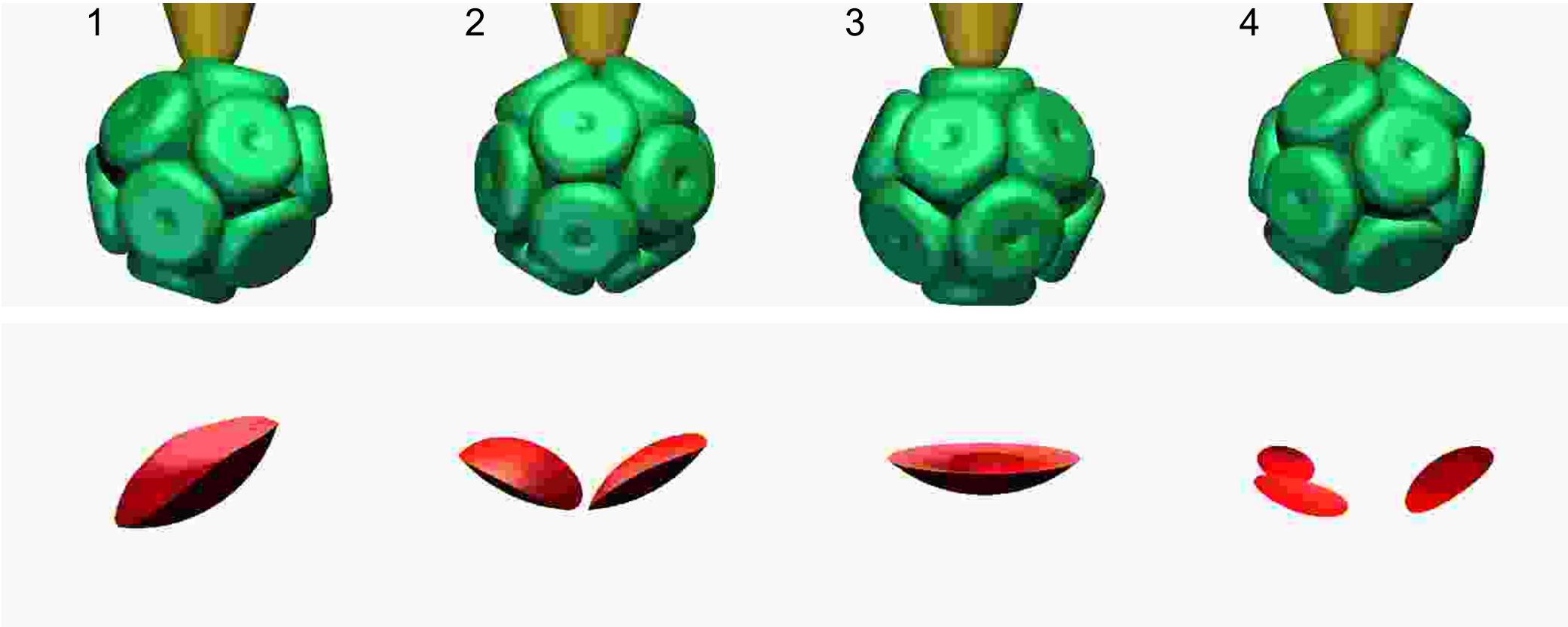


0.26 G_0 0.25 G_0 0.26 G_0 0.17 G_0

Spectroscopy of molecular orbitals



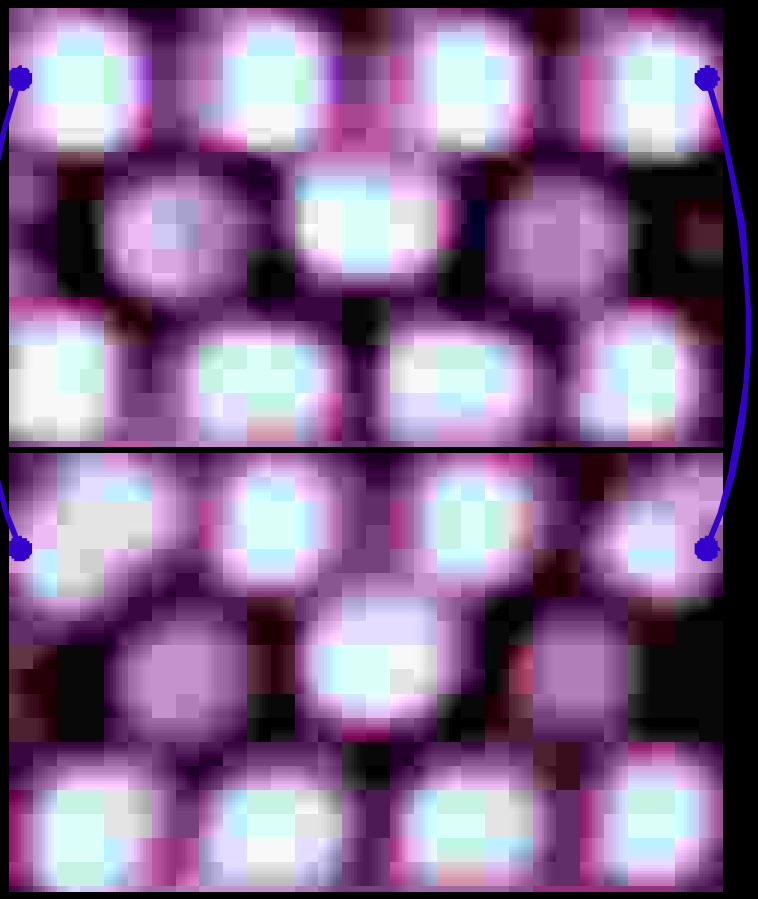
Overlap of orbitals



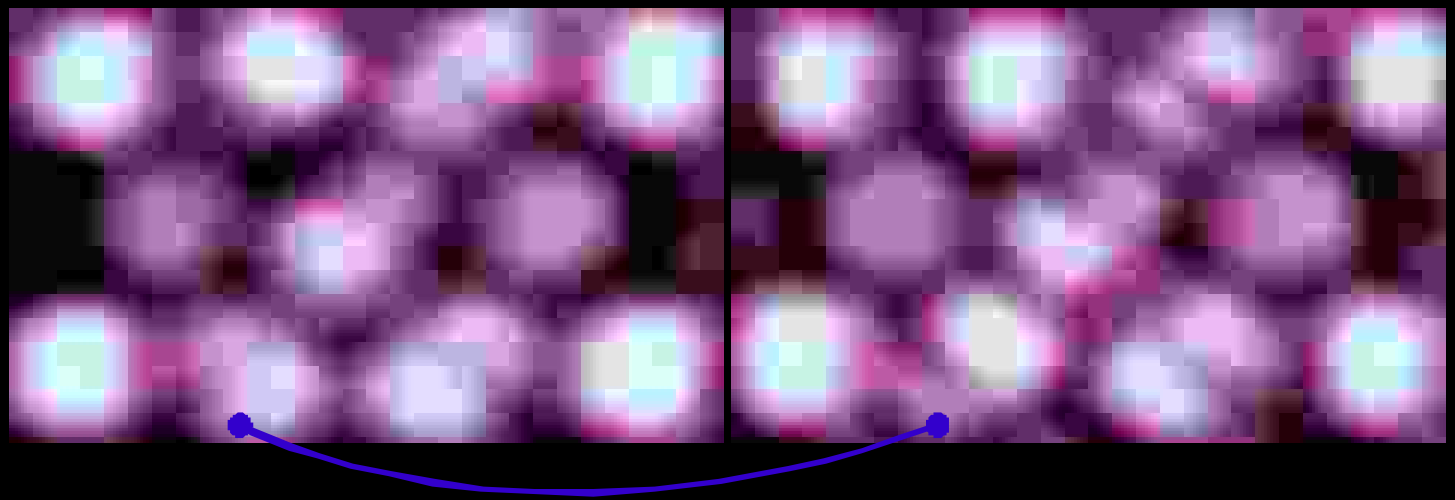
Conducting strongly → Conducting weakly

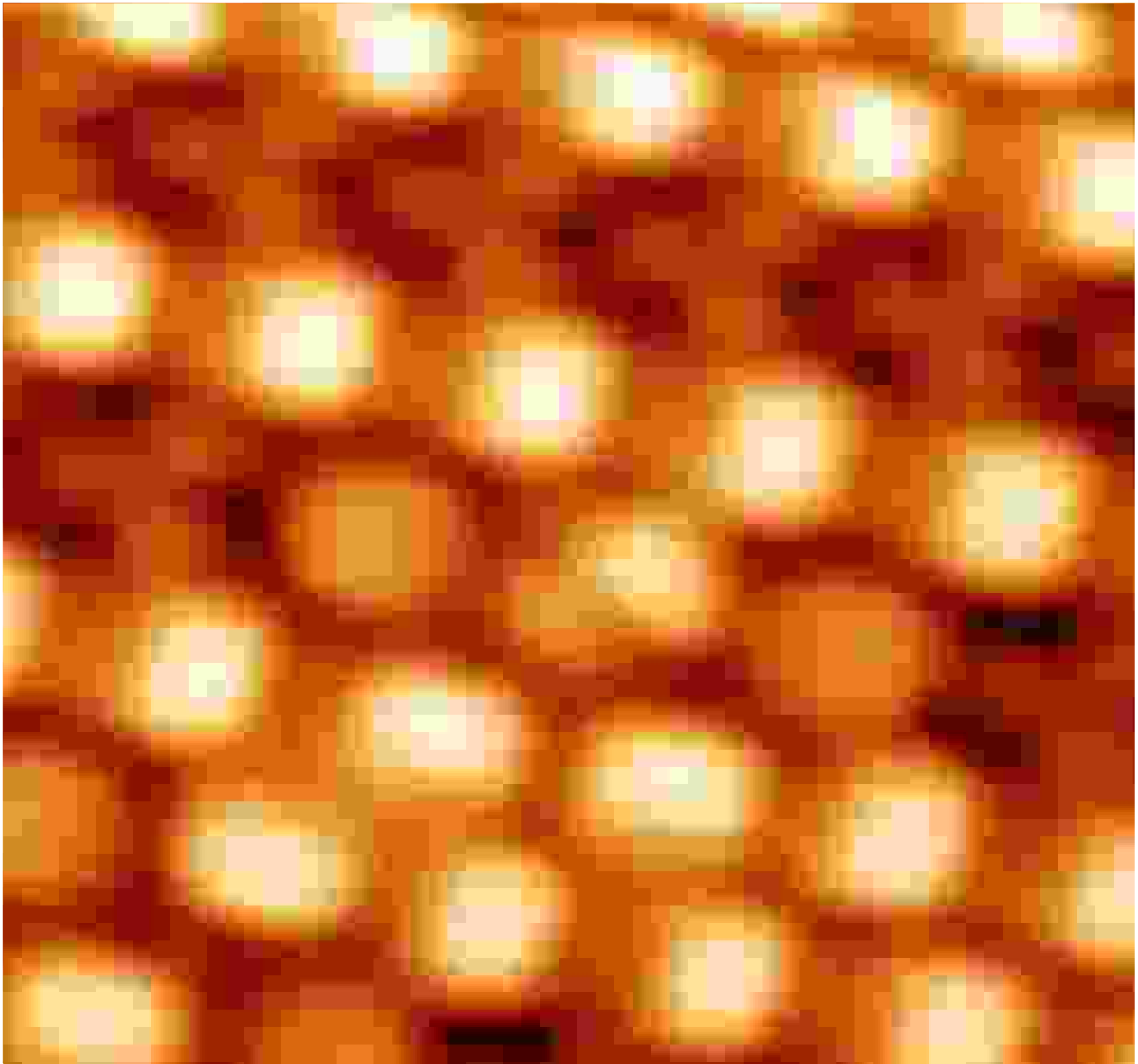
Rotation in a single-molecule contact

SFB 677:
Function by Switching

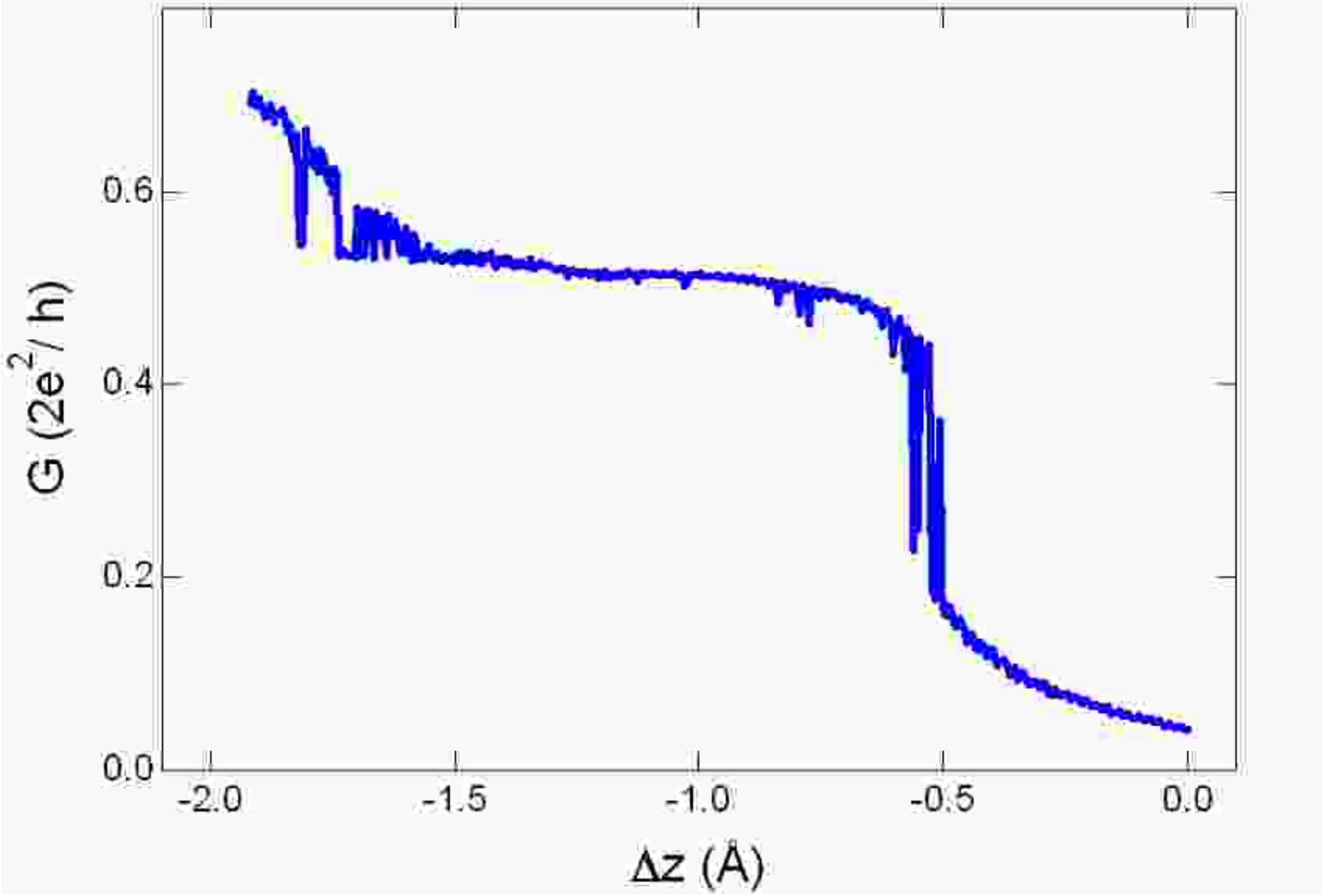


Néel, Limot, Kröger, Berndt
PRB **77**, 125431 (2008)





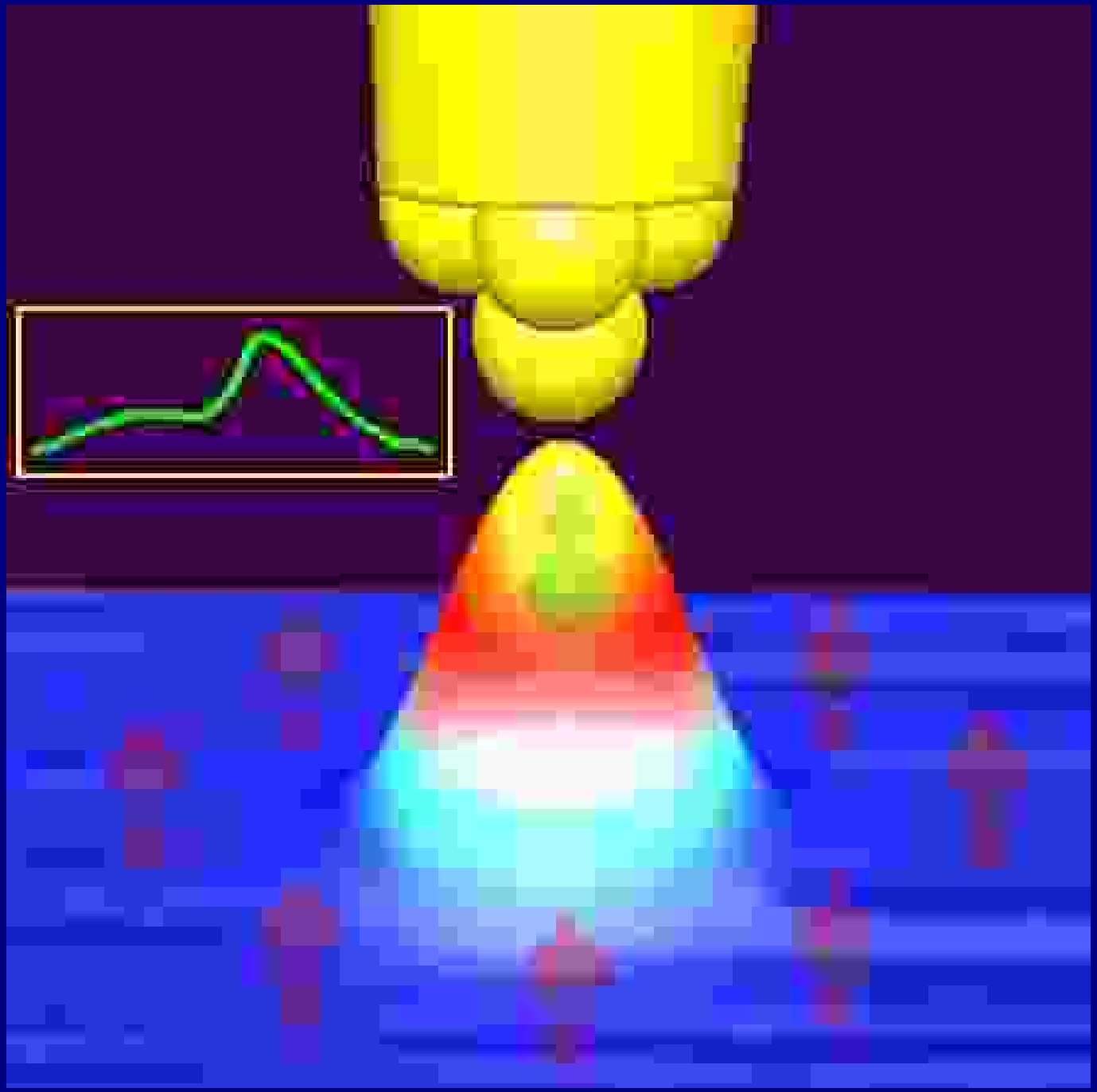
Threshold behaviour



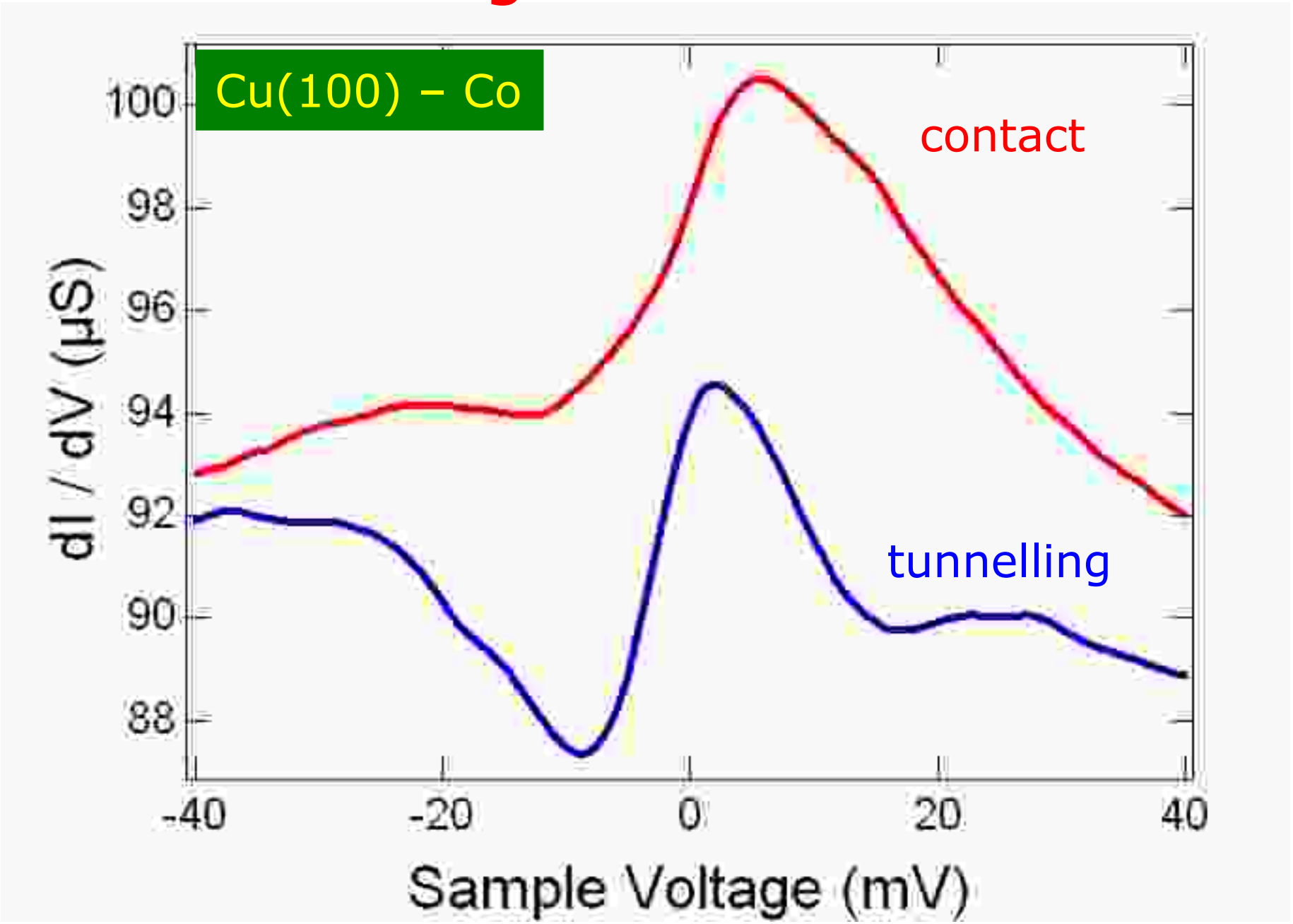
Controlled contact to magnetic atoms

SFB 668: Magnetism from the single atom to the nanostructure

Kondo effect of magnetic impurities

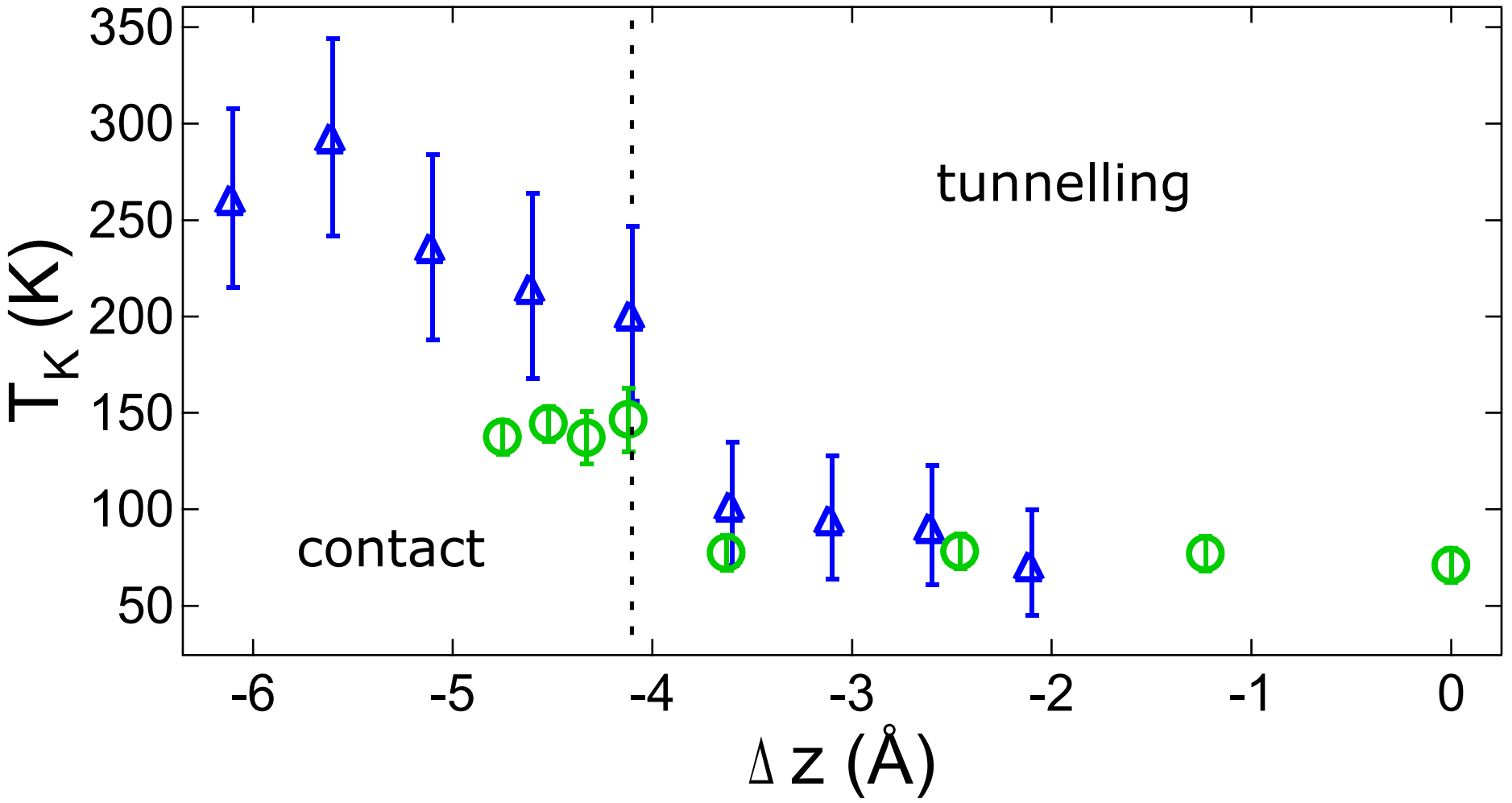


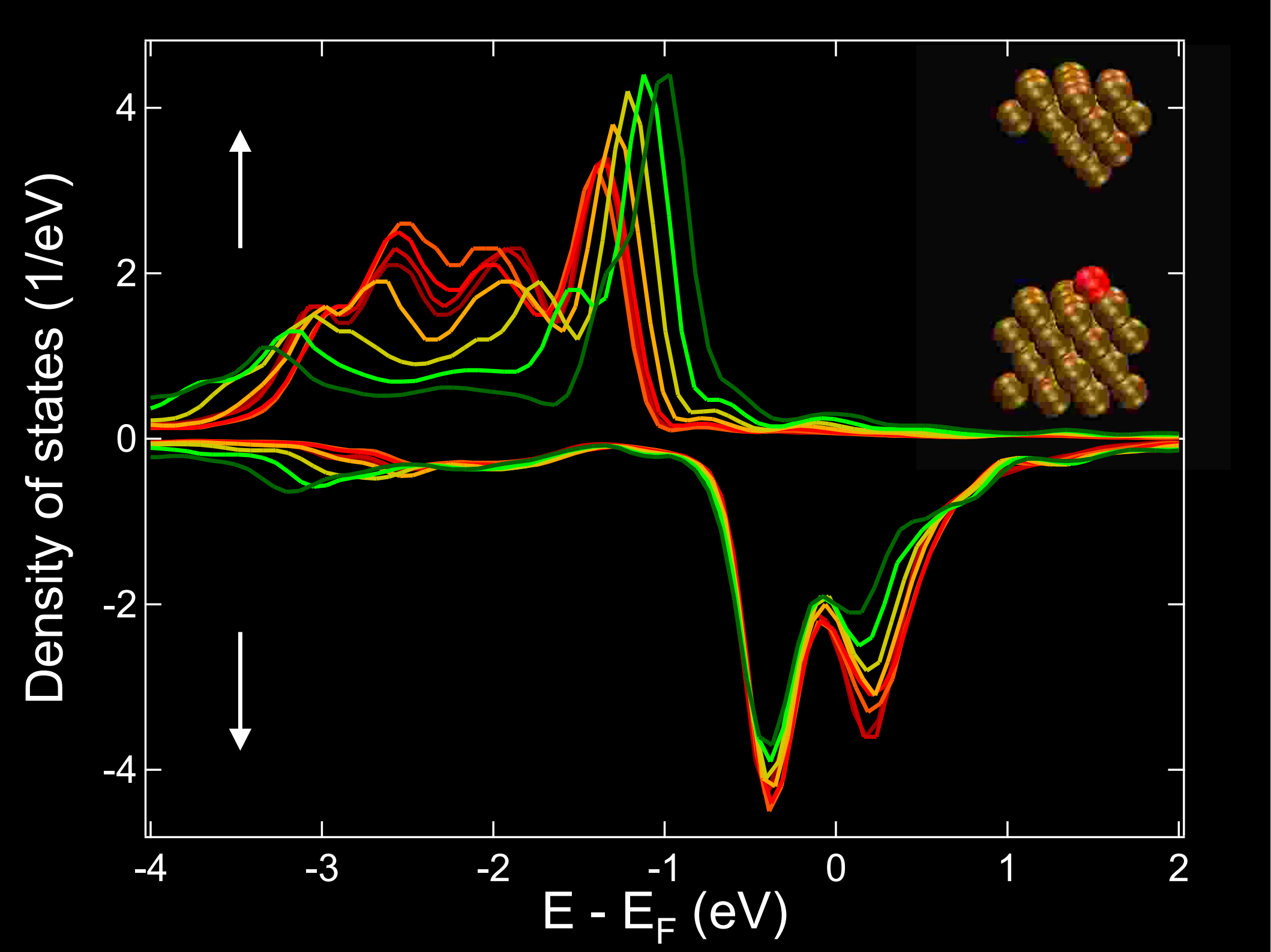
Broadening of Kondo resonance



Néel, Kröger, Limot, Berndt, Palotas, Hofer, PRL **98**, 016801 (2007)

Increase of Kondo temperature




Density of states (1/eV)
4
2
0
-2
-4
-4
-3
-2
-1
0
1
2
E - E_F (eV)

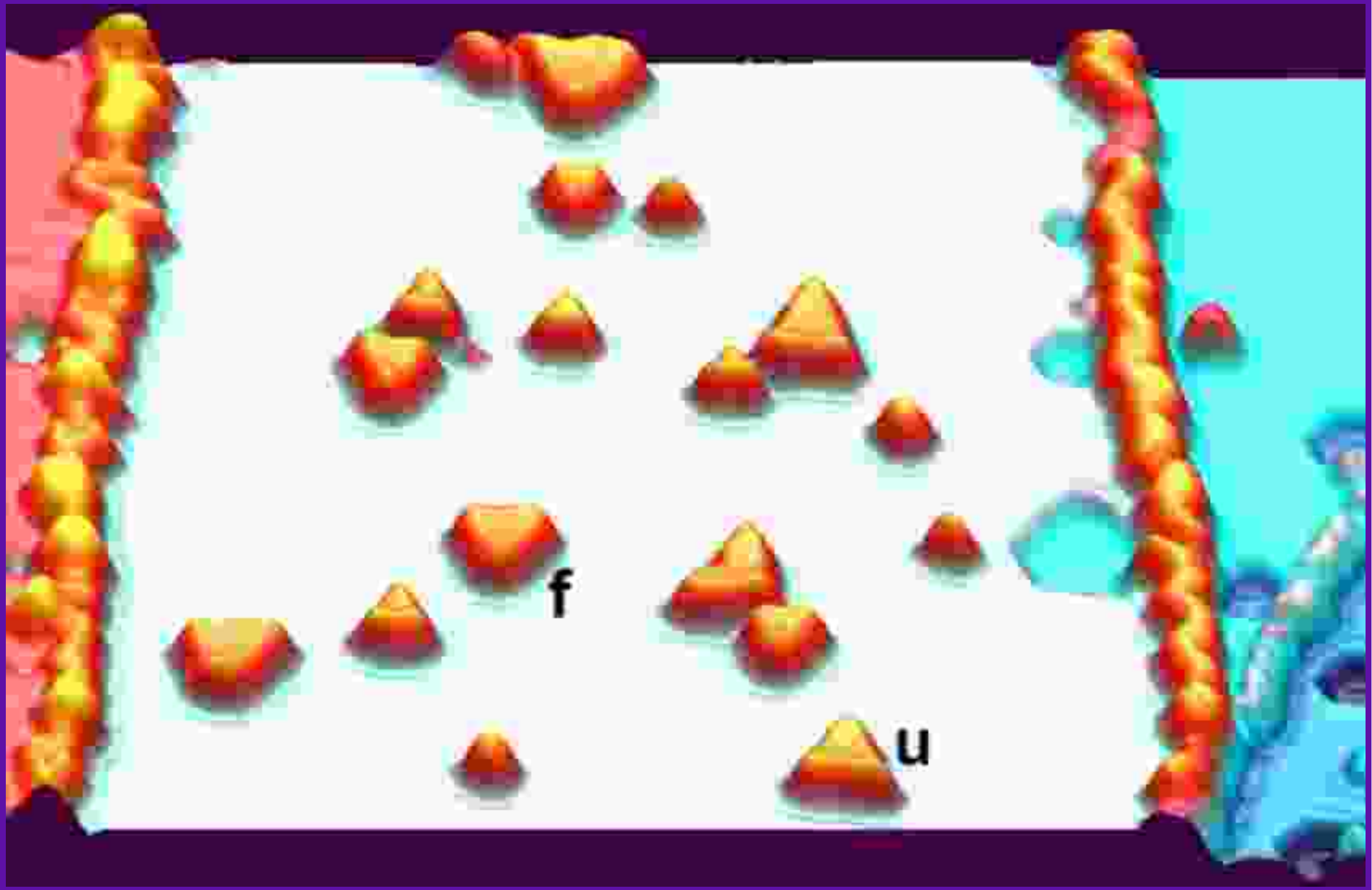
Spin-integrated transport

$$G = \frac{2e^2}{h} \sum_i \tau_i$$

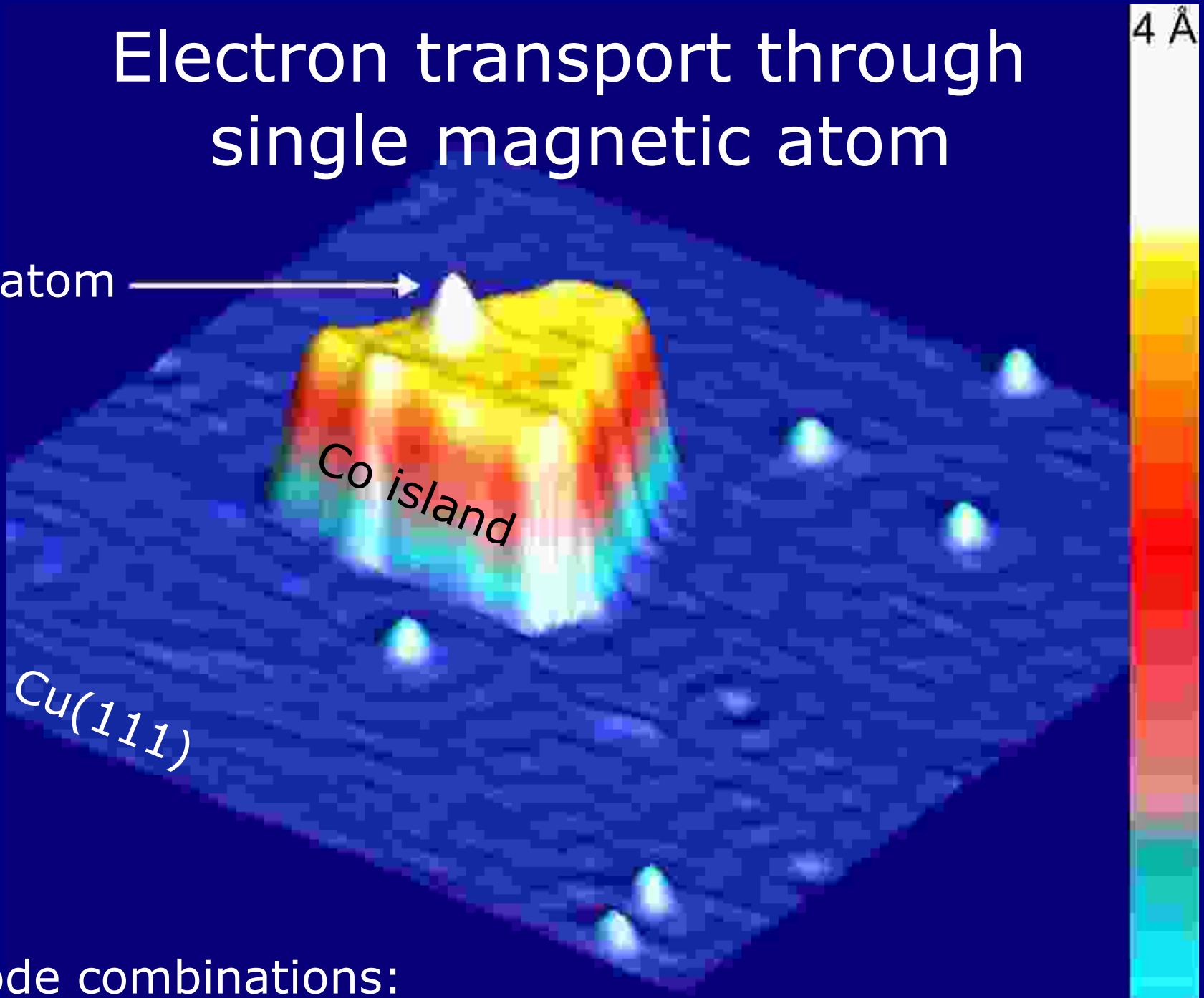
Spin-polarized transport

$$G = \frac{e^2}{h} \left(\sum_i \tau_i^{\uparrow} + \sum_i \tau_i^{\downarrow} \right)$$

Cobalt islands on Cu(111)



Electron transport through single magnetic atom



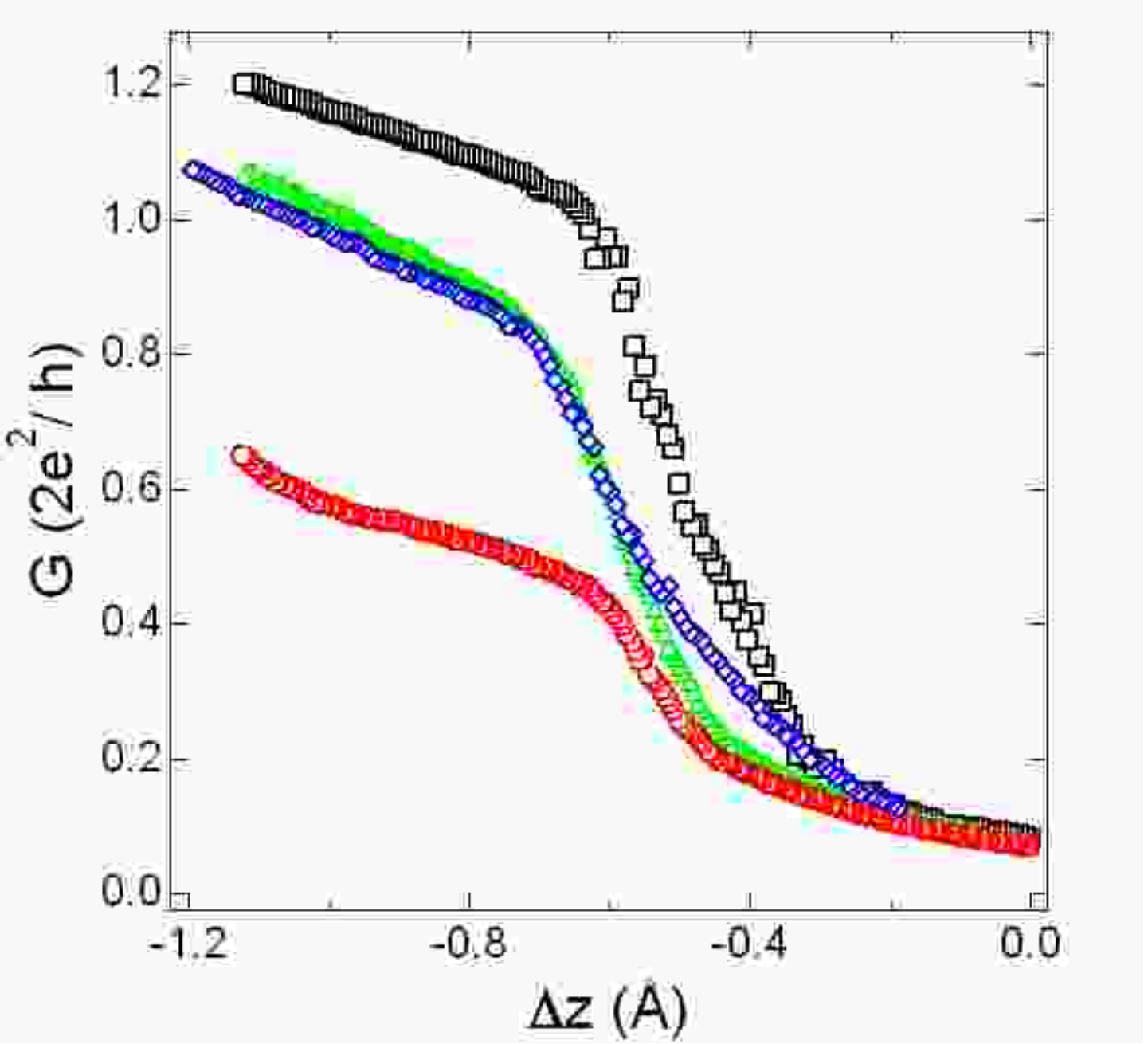
Electrode combinations:

Cu – Co – Cu Cu – Co – Co Ni – Co – Co

Cu – Co – Cu: ≈ 1.0 G_0

Cu – Co – Co:
Ni – Co – Cu: ≈ 0.8 G_0

Ni – Co – Co: ≈ 0.5 G_0



Néel, Kröger, Berndt, Brandbyge, in preparation

Summary

Kröger, Néel, Limot, J. Phys.: Condens. Matter, at press

Outlook

- Extension to other molecules
- Time-resolved fluctuations
- Vibration spectroscopy
- Spin-polarized transport