Max-Planck Research Group

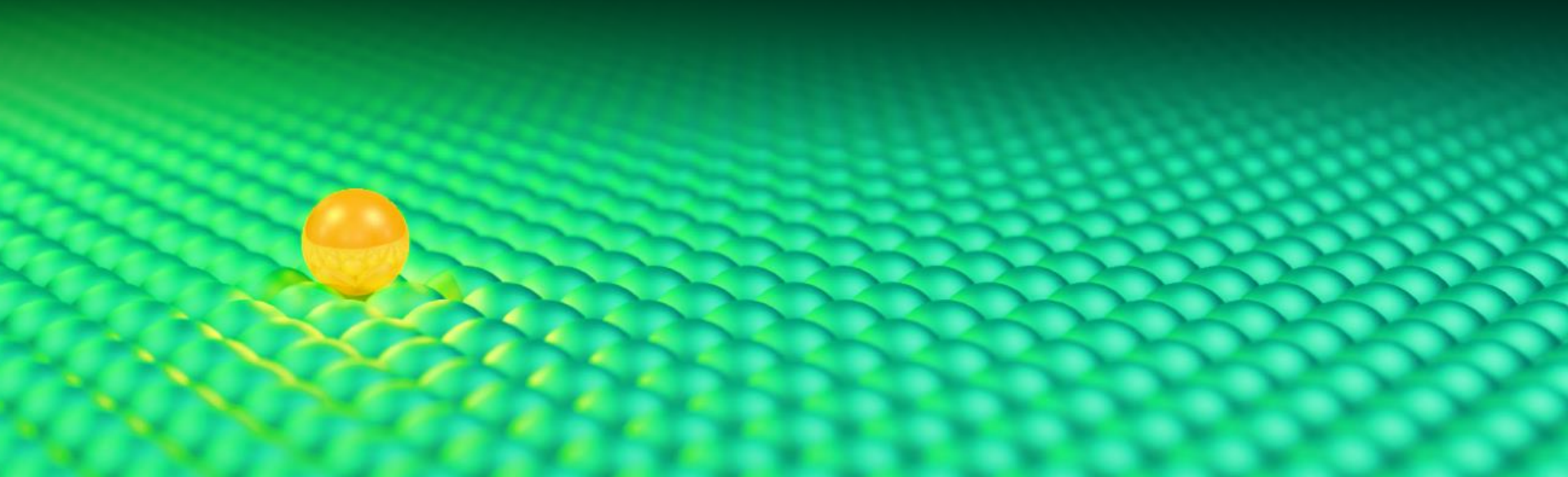
Dynamics of Nanoelectronic Systems

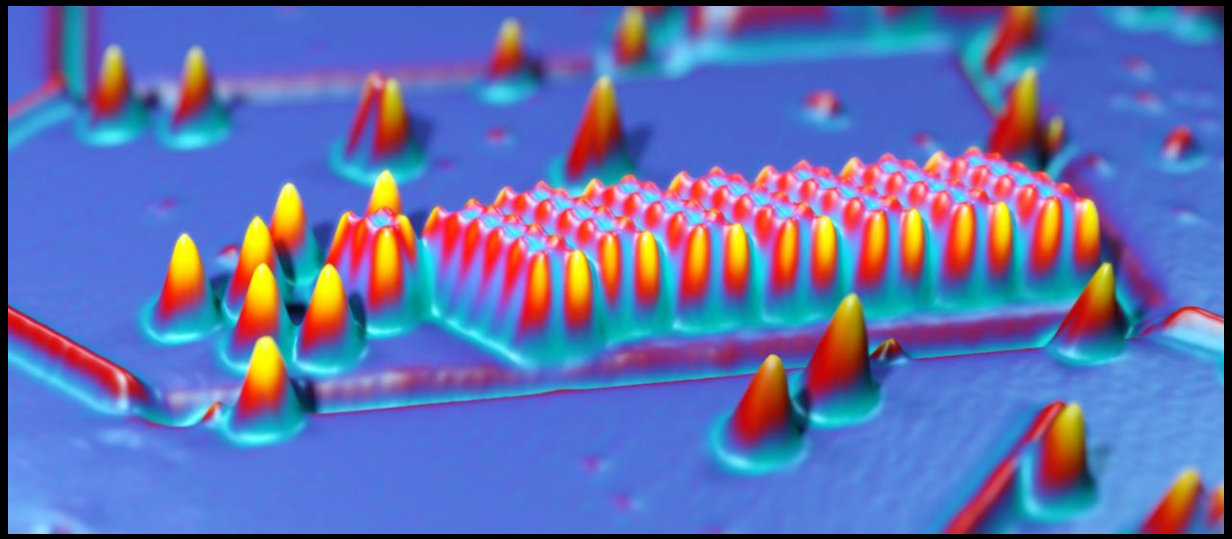
Atomically assembled antiferromagnets

Sebastian Loth

MPI Structure and Dynamics of Matter, Hamburg

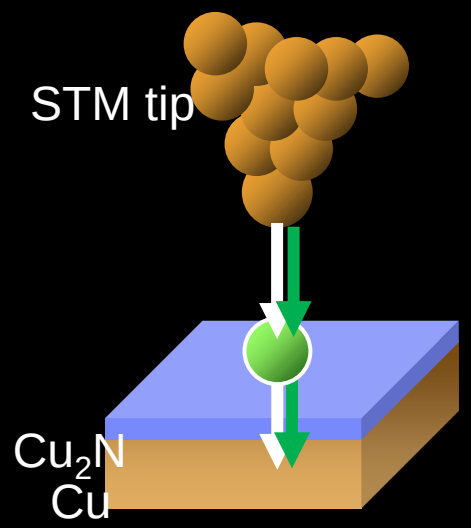
MPI Solid State Research, Stuttgart

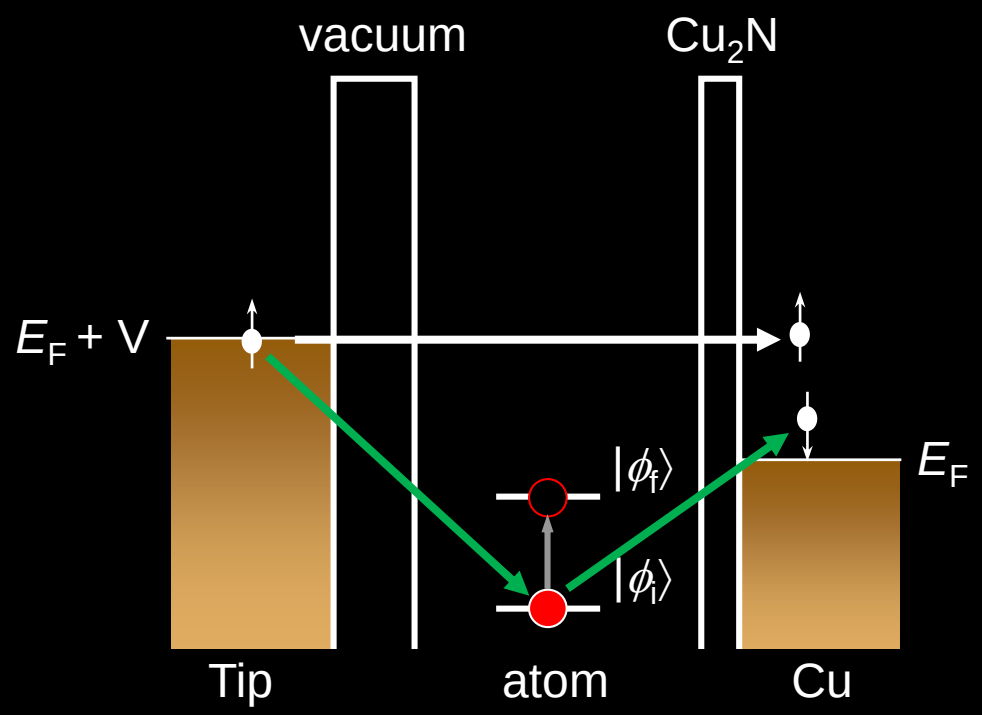




Can we create functionality in just a few atoms?

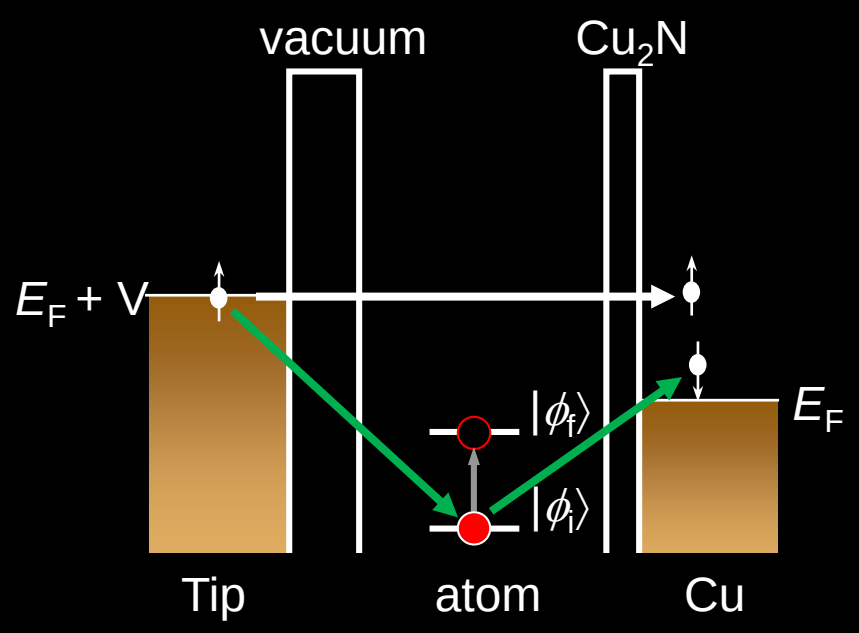
Spin excitation spectroscopy

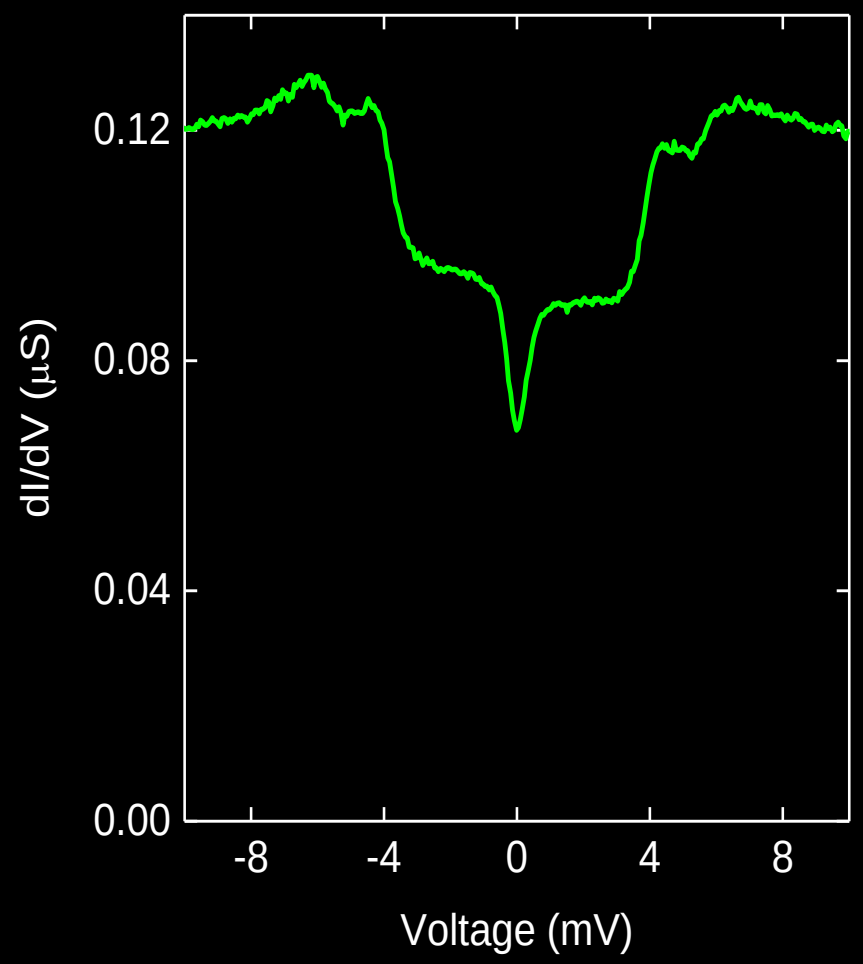




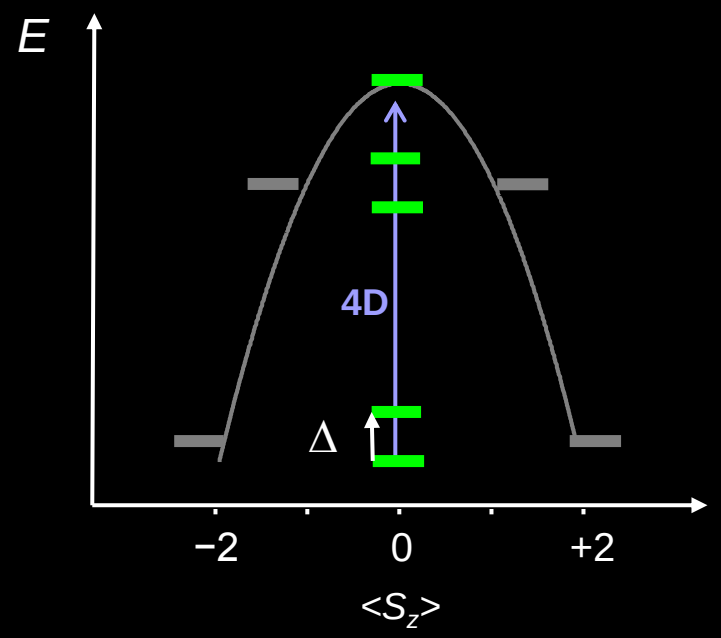
Inelsastic cotunneling STM Theory:
Fernandez-Rossier PRL 2009
Fransson Nano Lett. 2009
Persson PRL 2009
Lorente, Gauyacq PRL 2009

Spin excitation spectroscopy

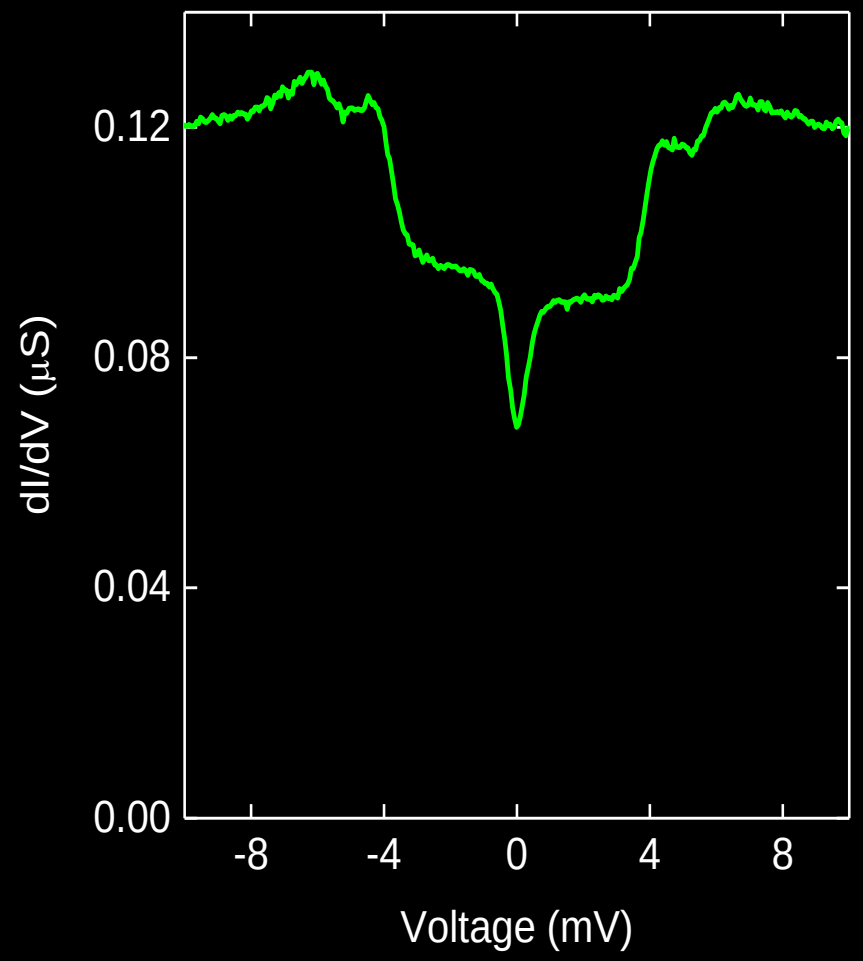




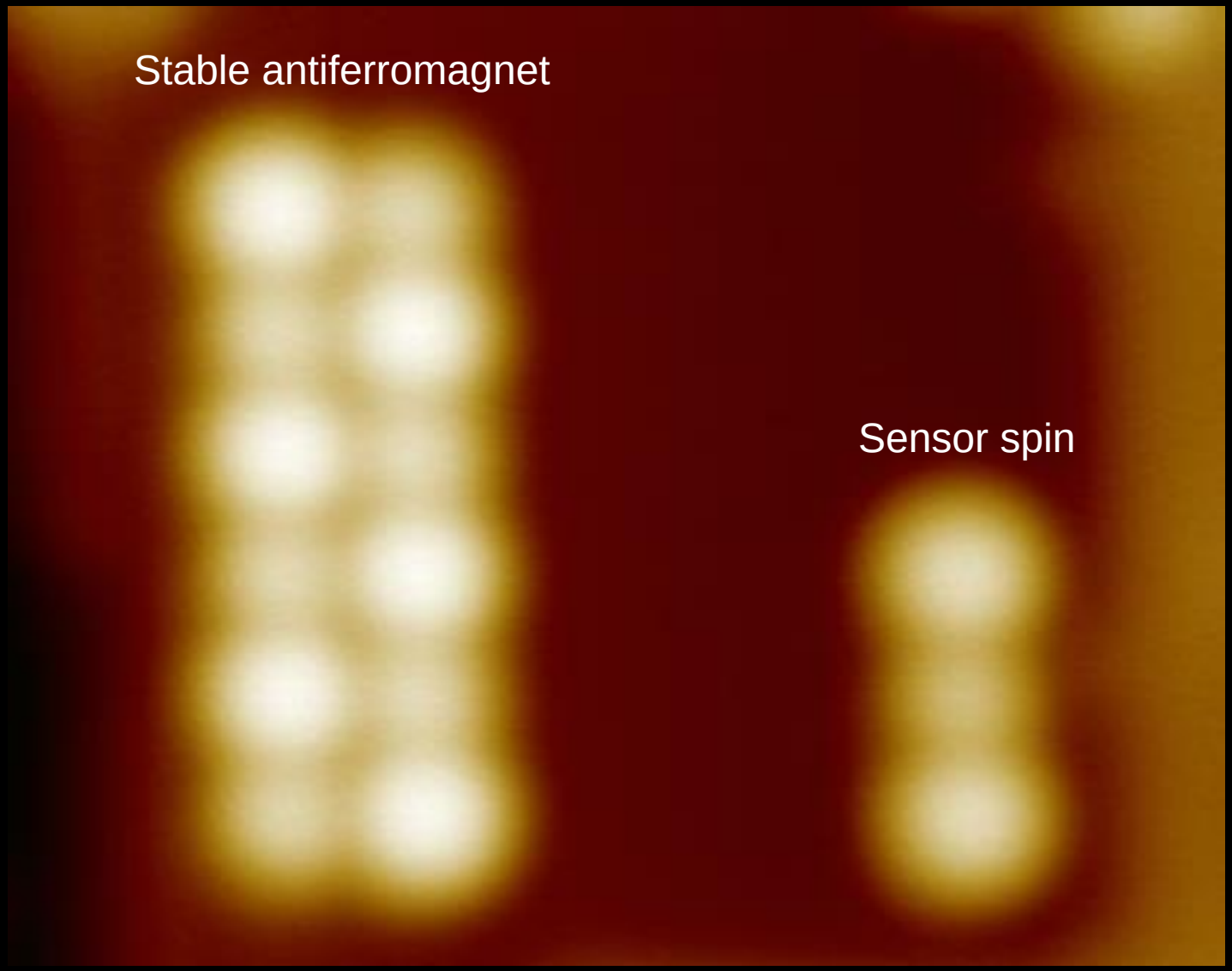
Spin excitation spectroscopy



$$H = DS_z^2 + \underline{\frac{E}{2}(S_+^2 + S_-^2)},$$

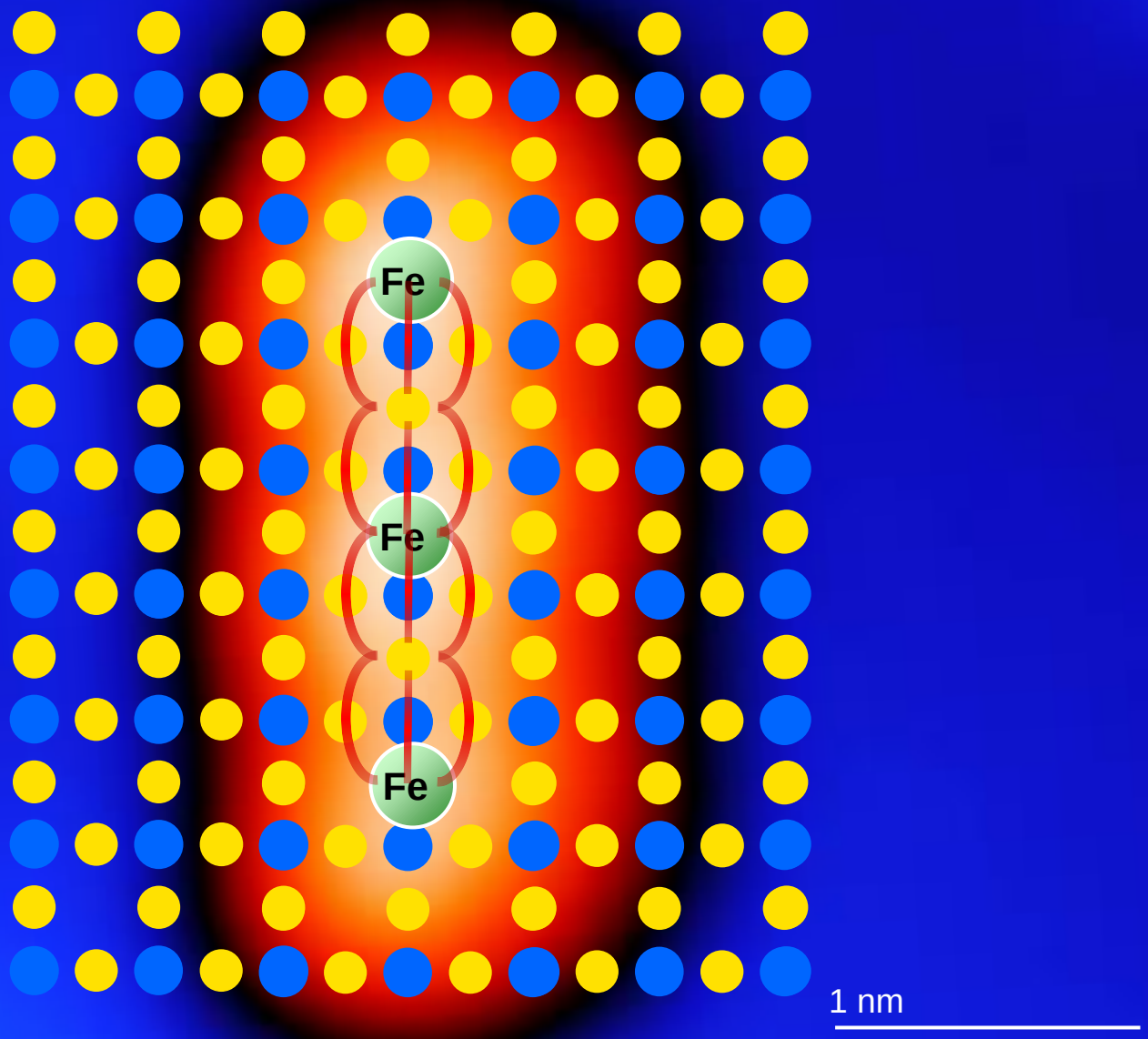


Spin sensing at the atomic scale

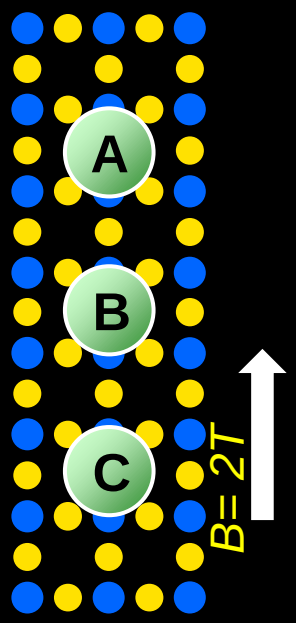


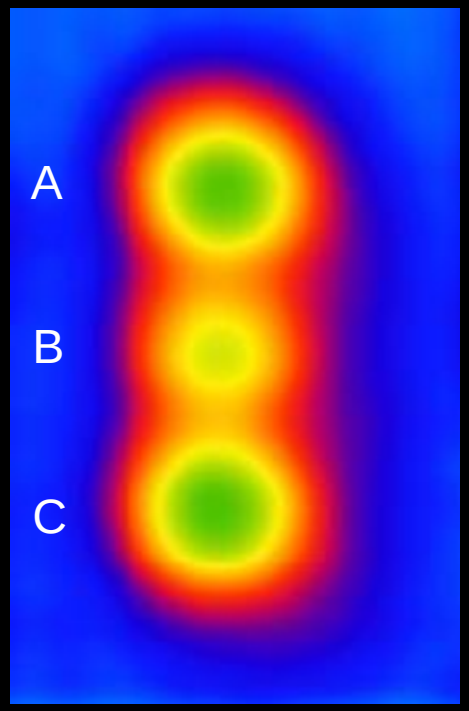
1 nm

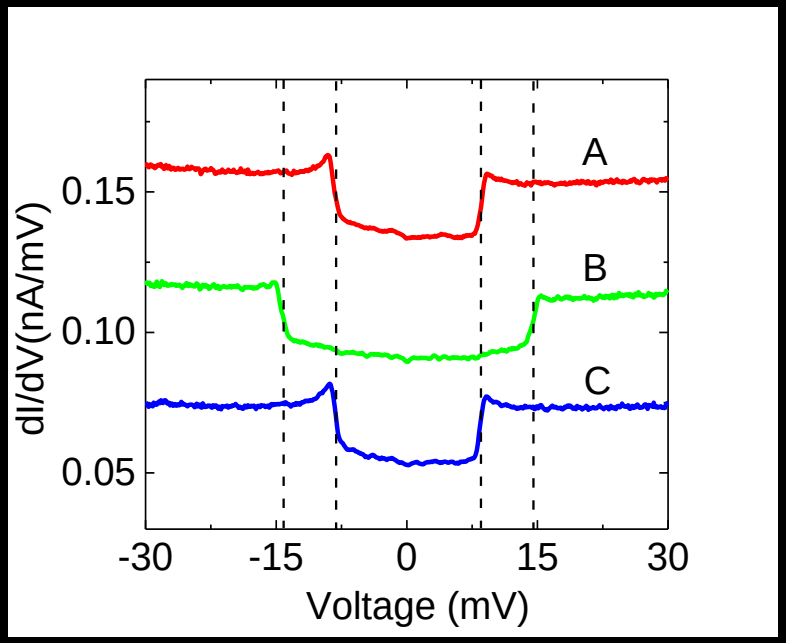
Fe_3 spins sensor



Spin relaxation time of Fe trimer



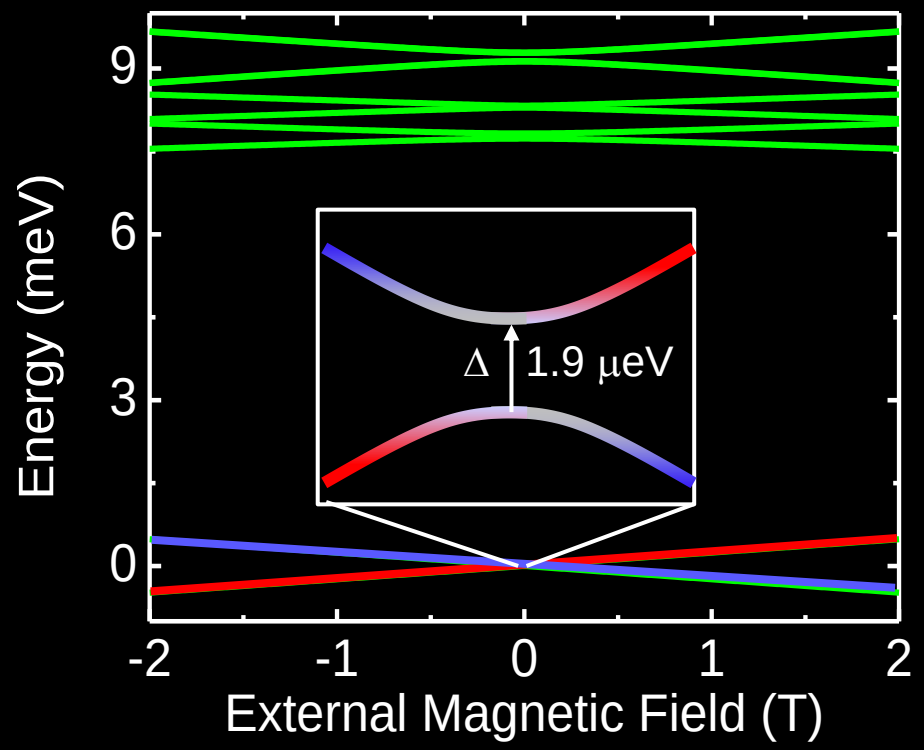




$$\hat{H}_s = \sum_i g\mu_B \vec{S}_{i,z} B_z + \sum_i D\hat{S}_{i,z}^2 + \sum_i E\left(\hat{S}_{i,x}^2 - \hat{S}_{i,y}^2\right) + J\left(\vec{S}_A\vec{S}_B + \vec{S}_B\vec{S}_C\right)$$

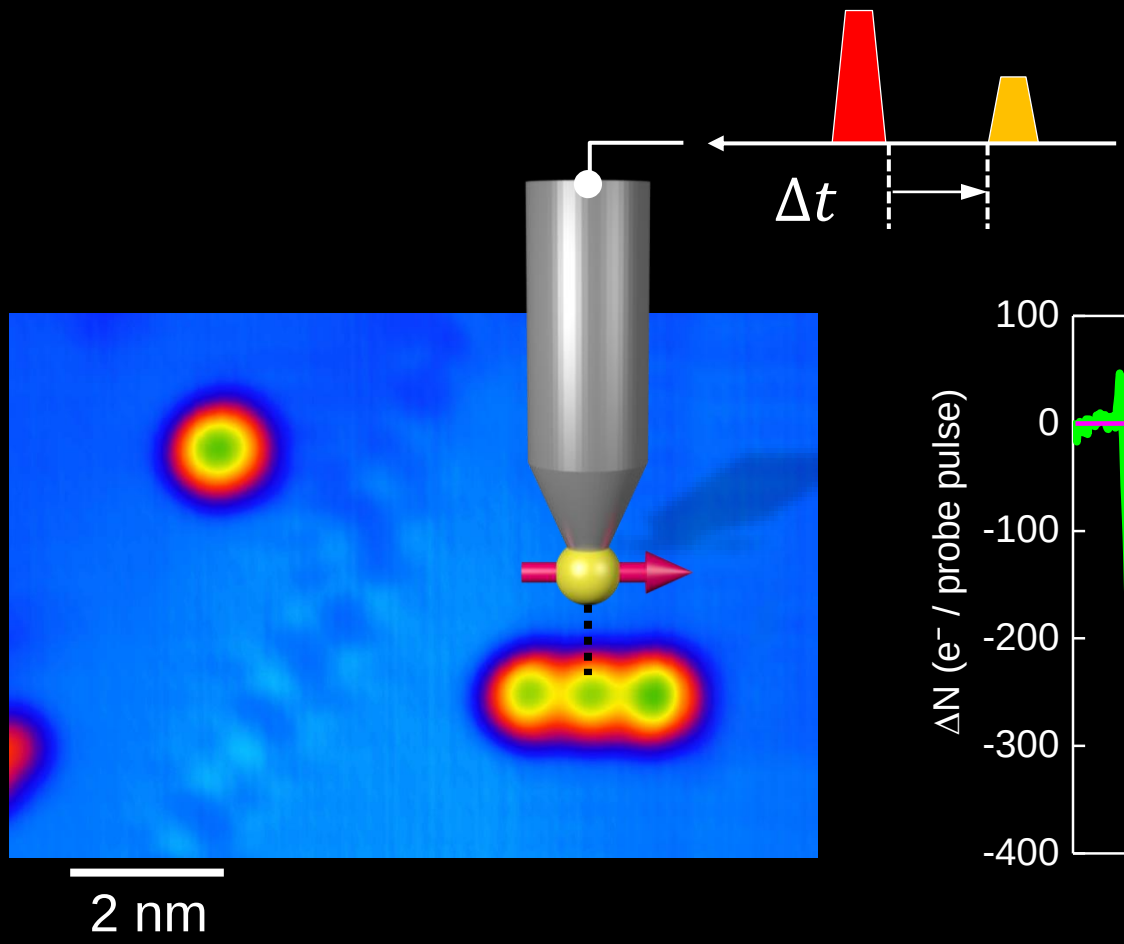
$D_{A,B,C}$ = {-2.1 meV, -3.6 meV, -2.1 meV}
E = 0.31 meV
J = 1.15 meV

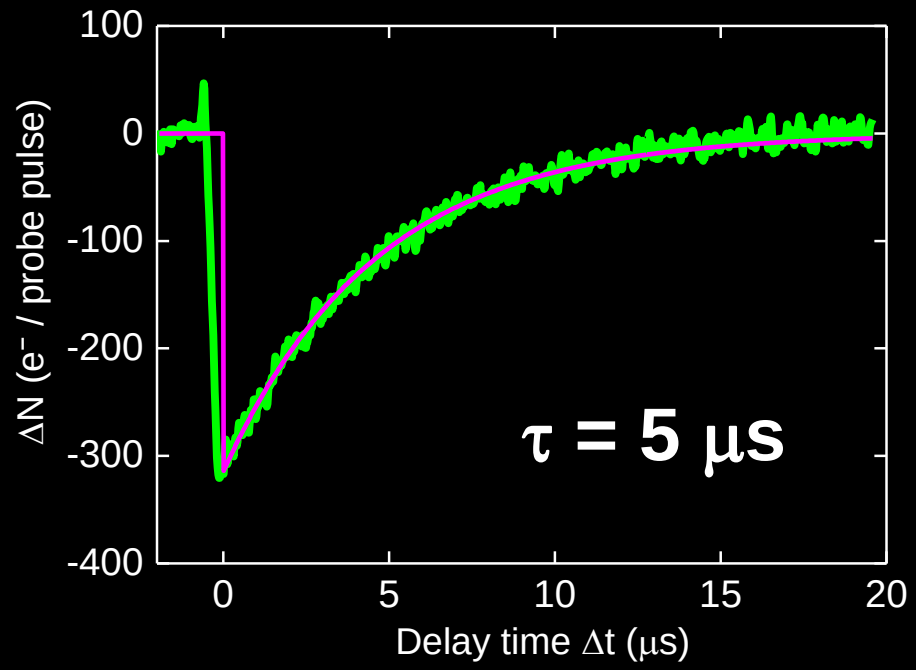
Spin state spectrum of Fe trimer



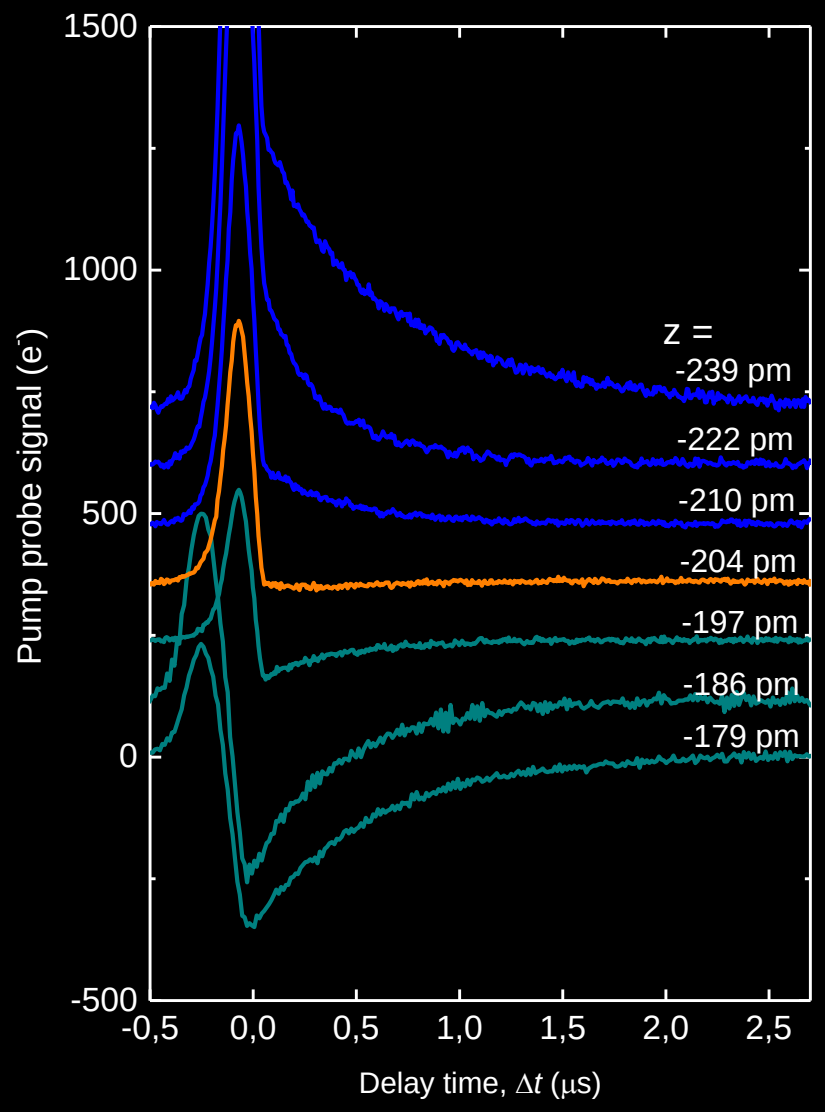
- Low energy spectrum:
  - two-level system with avoided level crossing

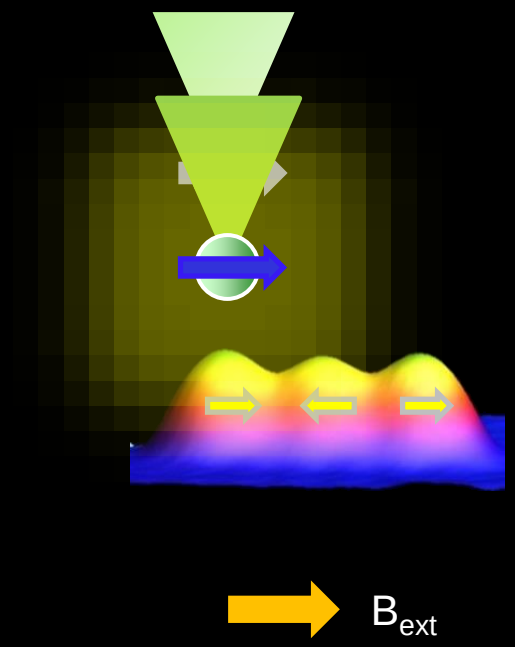
All-electronic pump probe spectroscopy





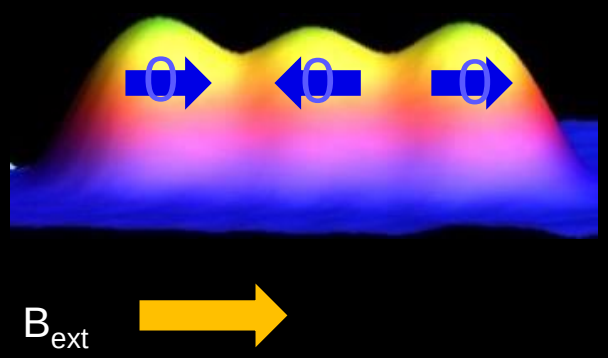
Atomic Exchange bias control

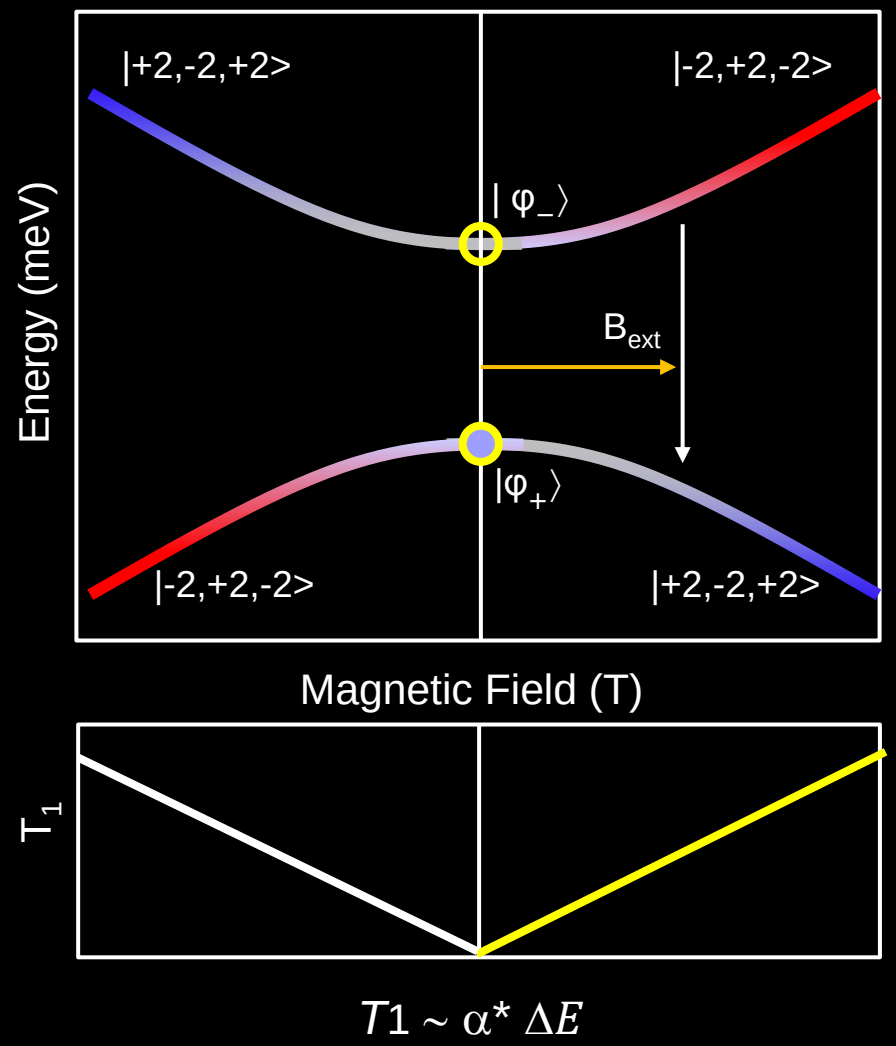




S. Yan, D.J. Choi, J.A.J Burgess, S. Rolf-Pissarczyk, S. Loth
Nature Nano 10 40 (2015)

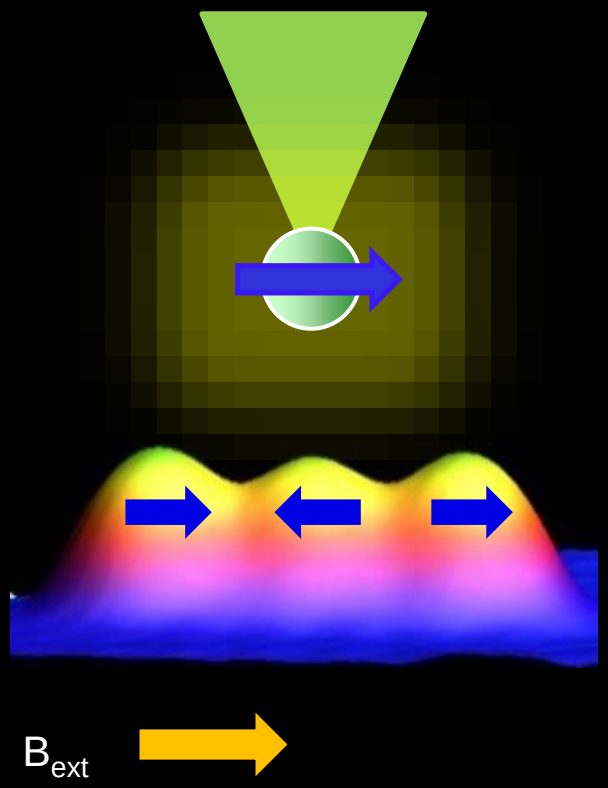
Controlled spin-environment interaction

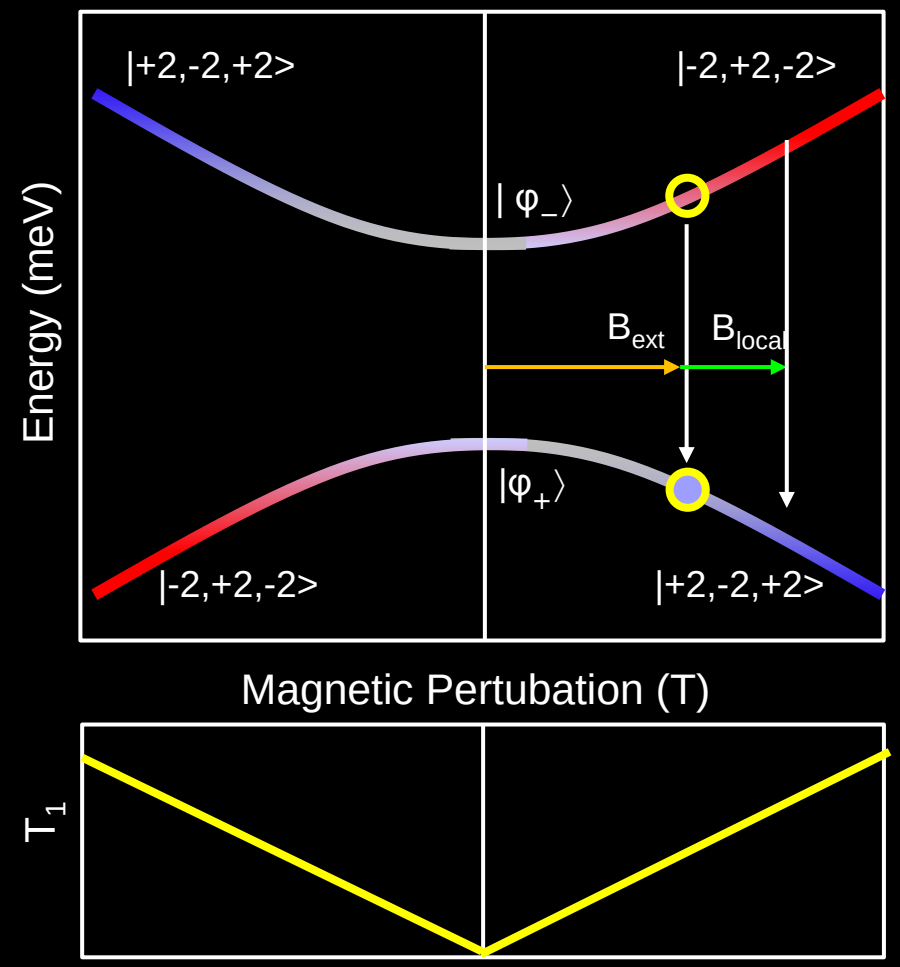




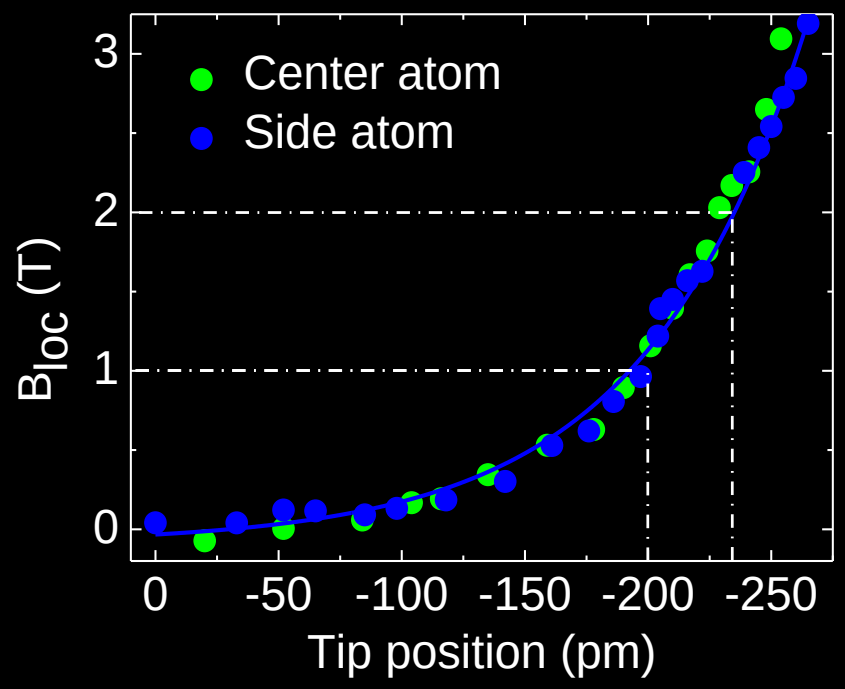
$T1 \sim \alpha^* \Delta E$

Controlled spin-environment interaction

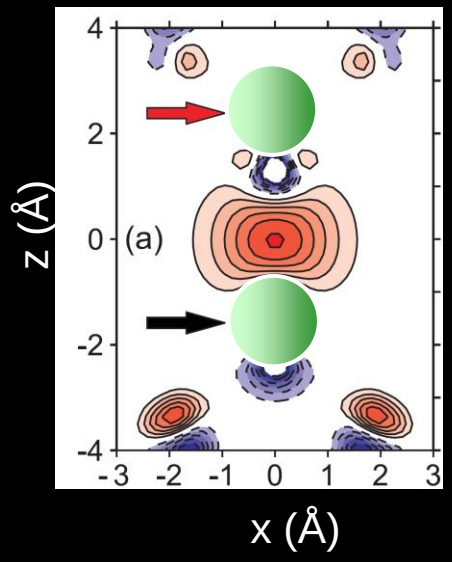




Atomic Exchange Bias field



Tao et al. PRL 103 057202 (2009)



S. Yan, D.J. Choi, J.A.J Burgess, S. Rolf-Pissarczyk, S. Loth
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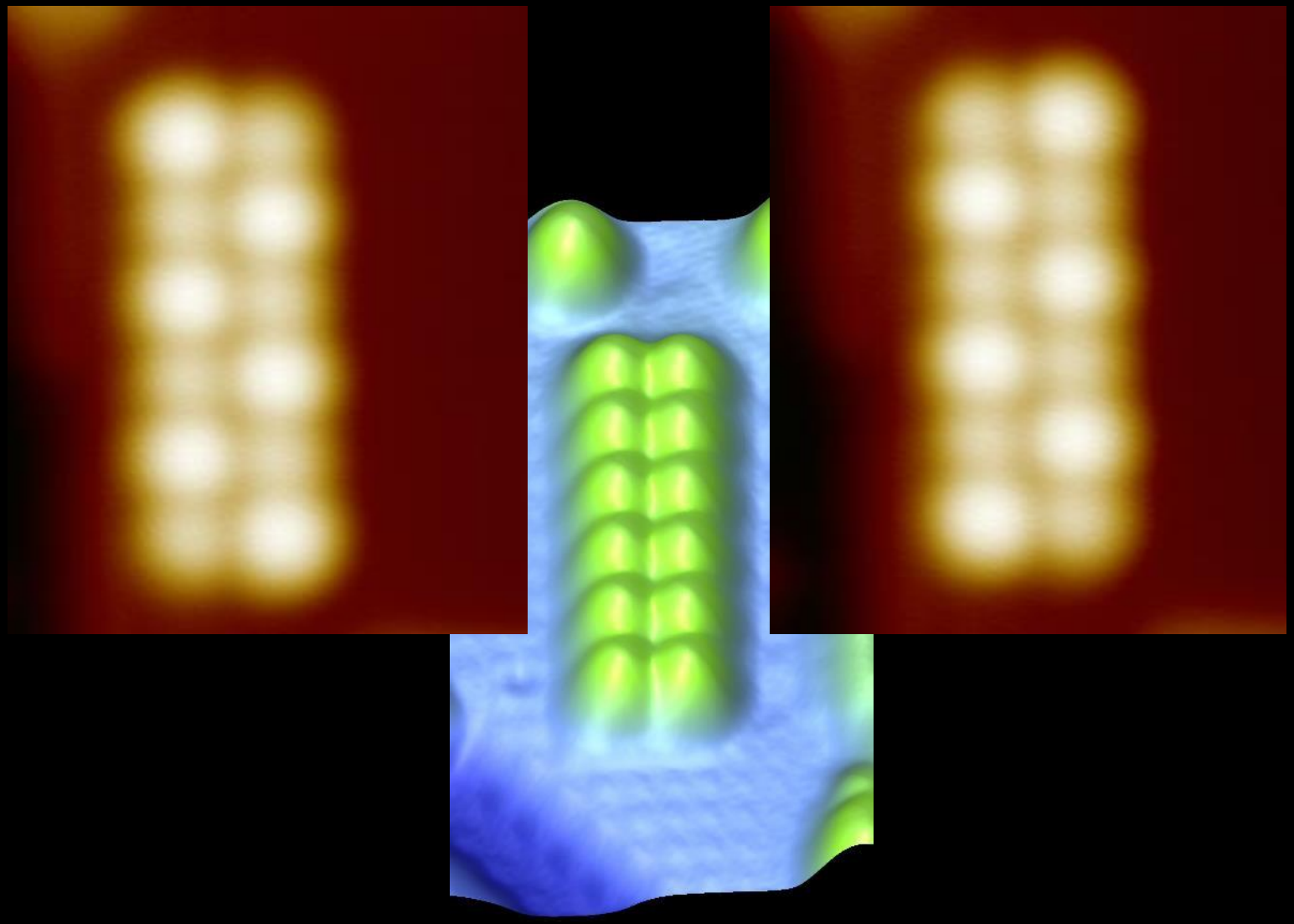
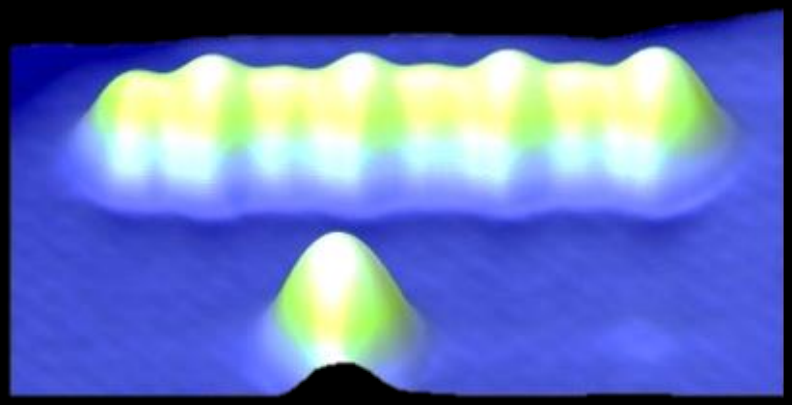
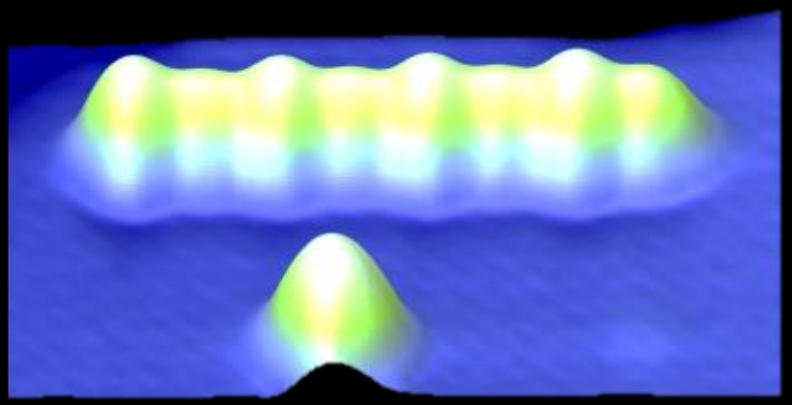
Stability at 0.5K >17h.



Néel states in few-atom nanomagnets

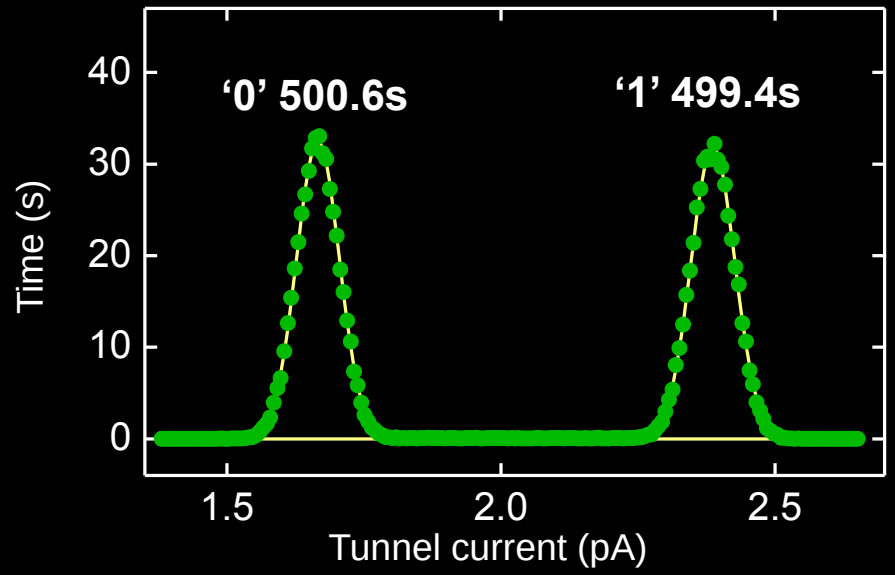


B = 3 T

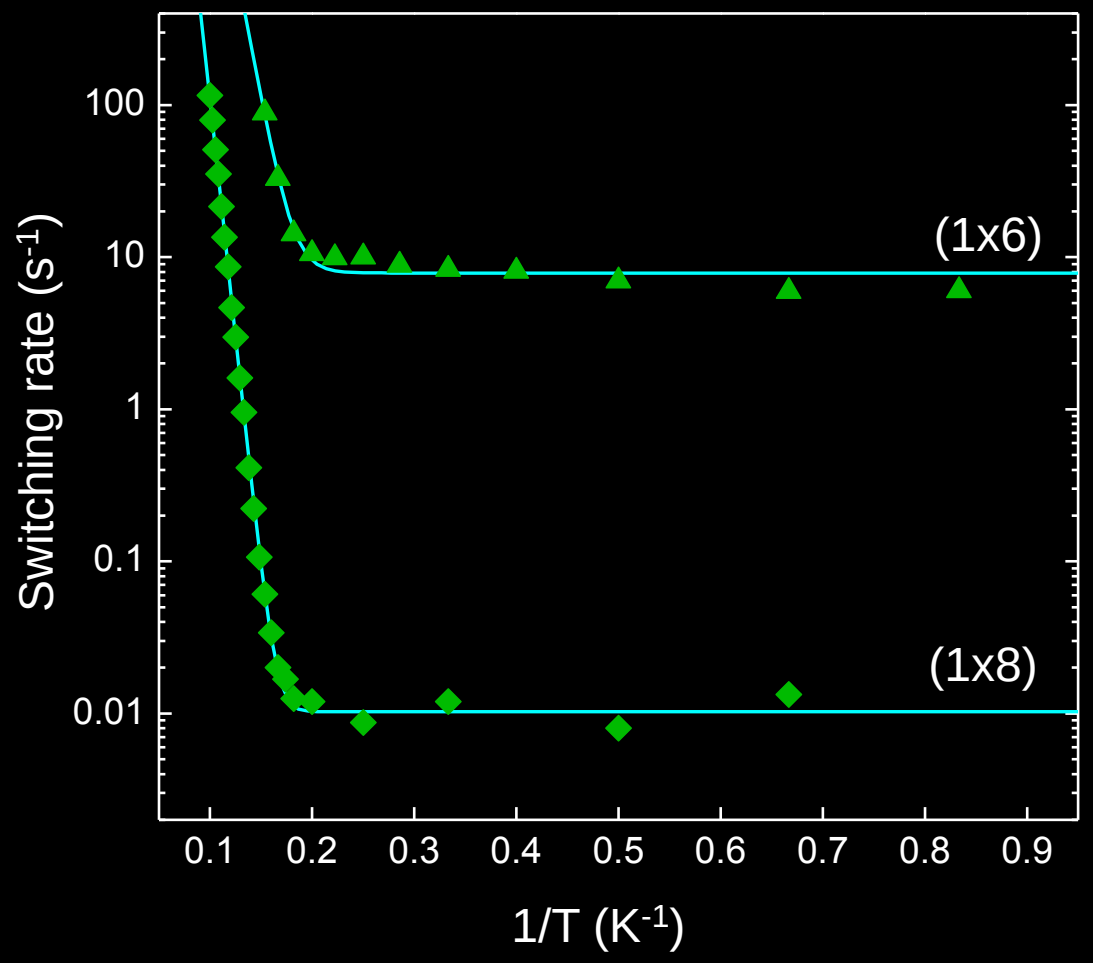


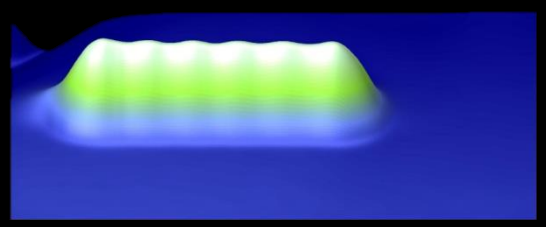
Néel state ‘0’

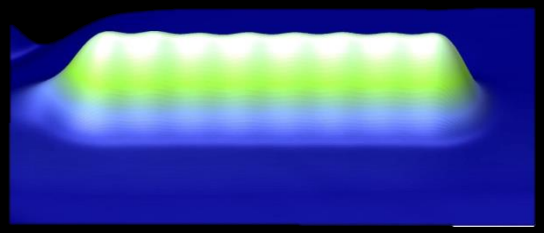
Néel state ‘1’



Magnetic stability in antiferromagnetic spin chains

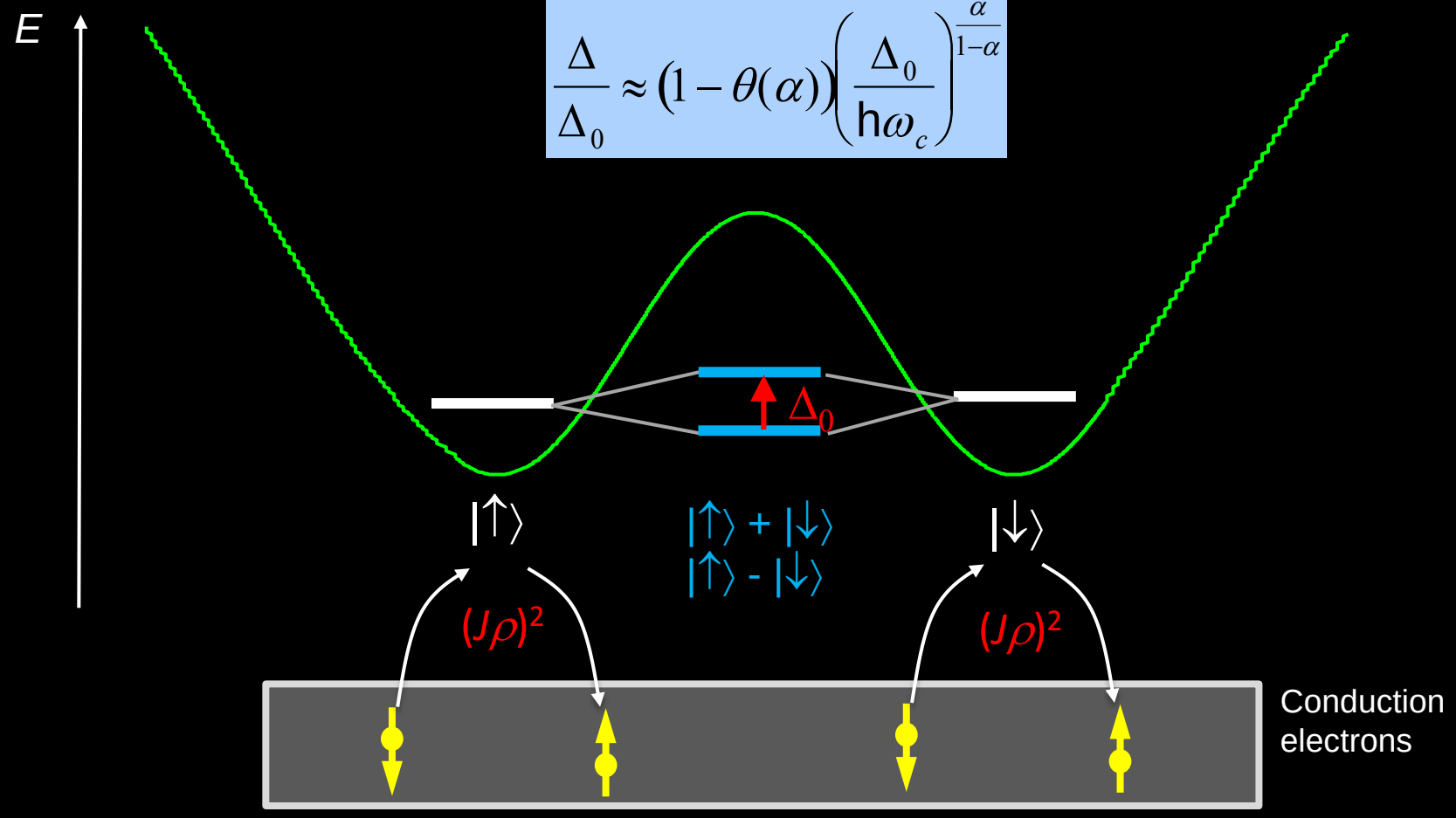






Quantum to Classical phase transition in spins

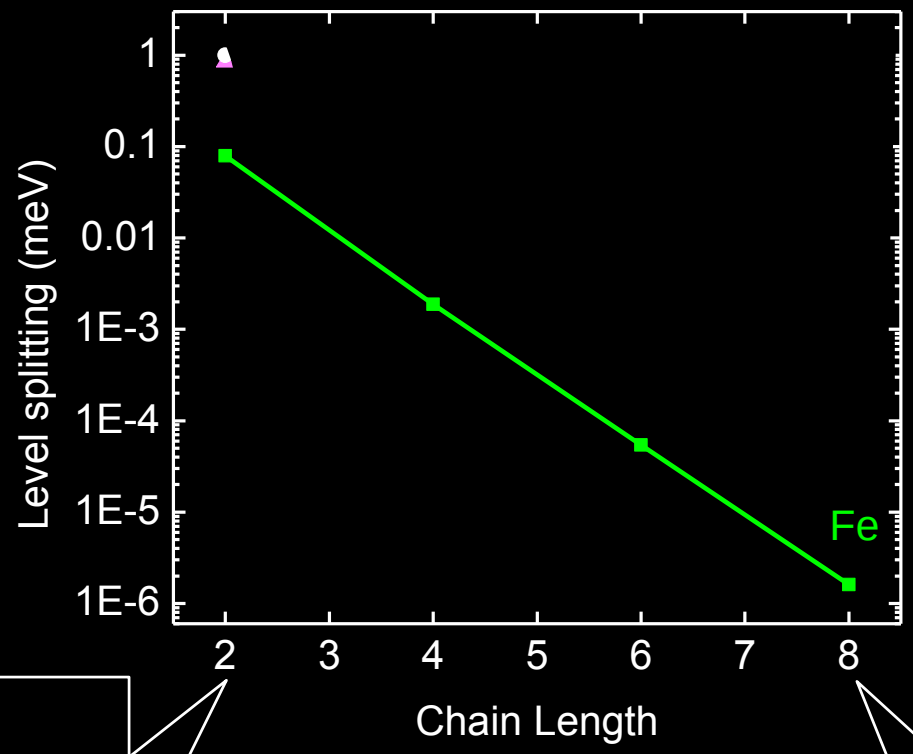
$$\frac{\Delta}{\Delta_0} \approx \left(1-\theta(\alpha)\right)\left(\frac{\Delta_0}{\hbar\omega_c}\right)^{\frac{\alpha}{1-\alpha}}$$

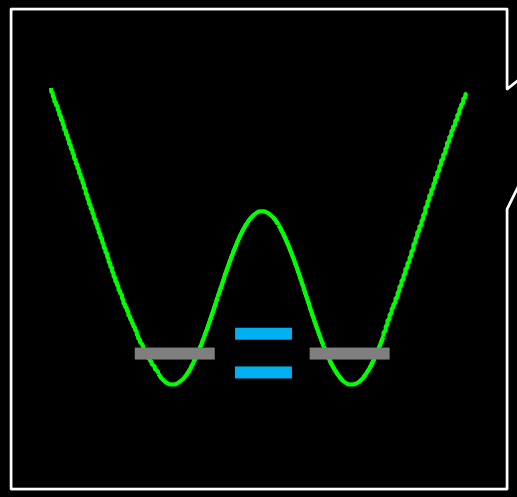


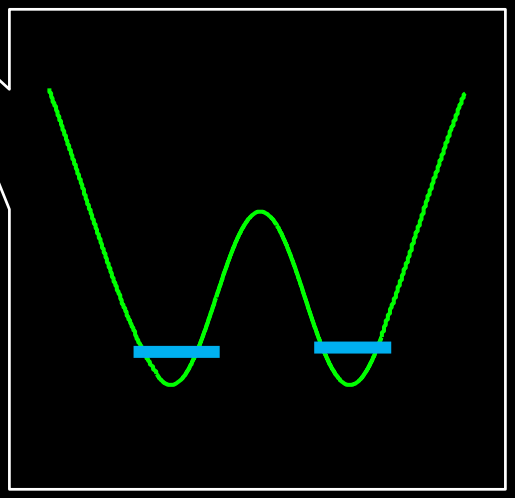
- **Localization by coupling to a classical bath**
  (Caldeira & Leggett 1981)

Thanks to:
Andy Millis

Quantum to Classical transition in spins

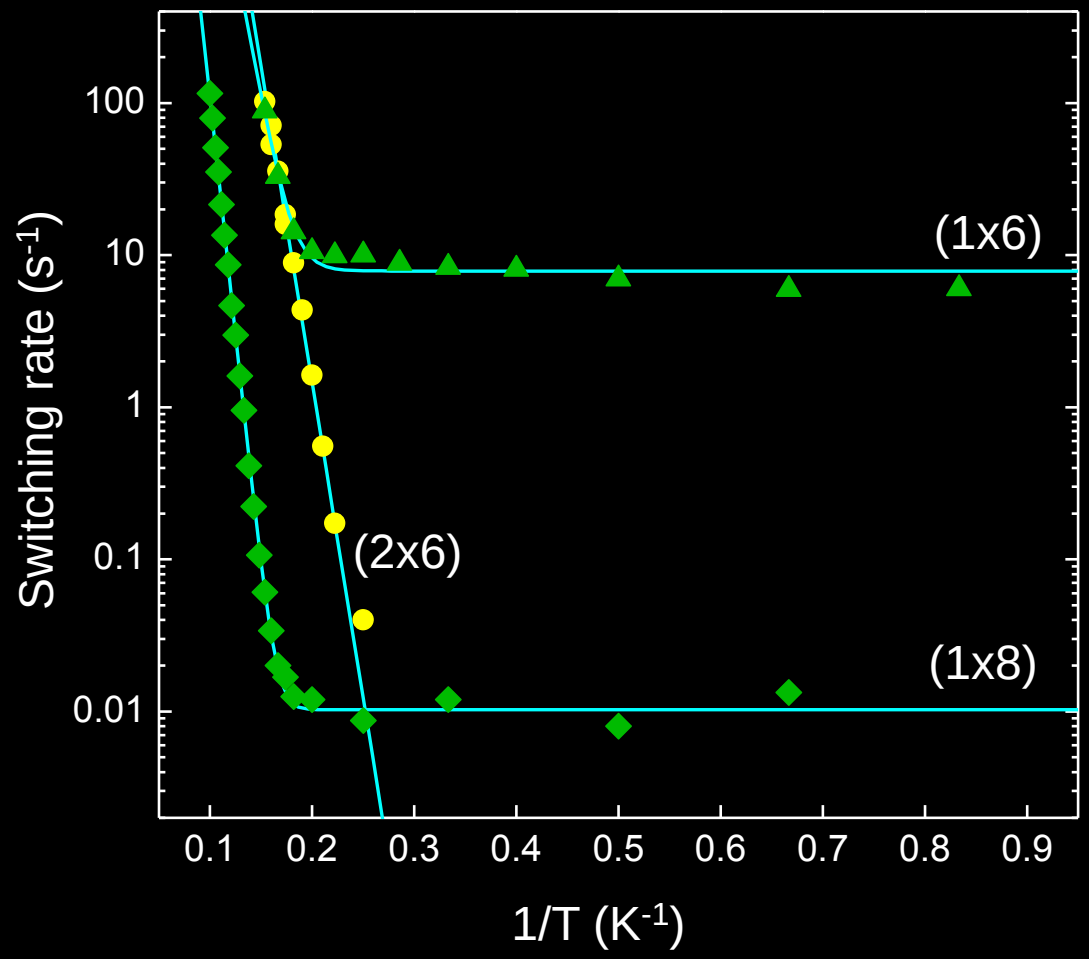


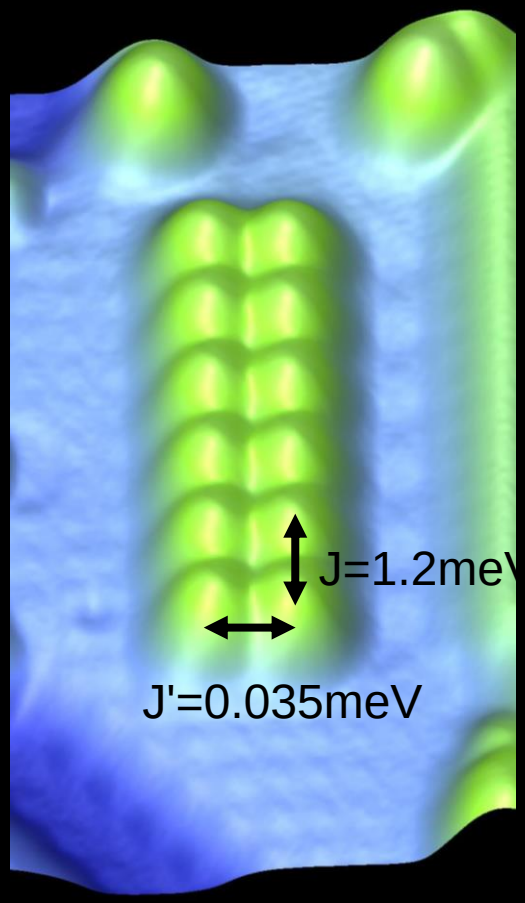




F. Delgado, S. M. Zybin, J. Fernandez Rossier EPL 2015

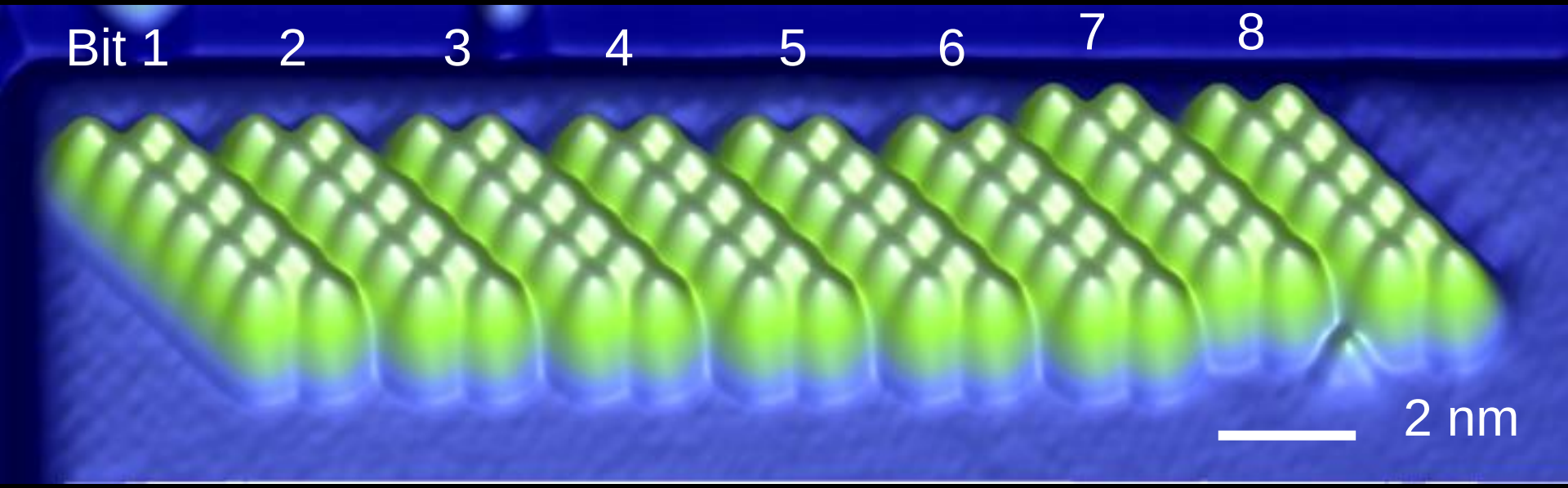
Magnetic stability in antiferromagnetic spin chains

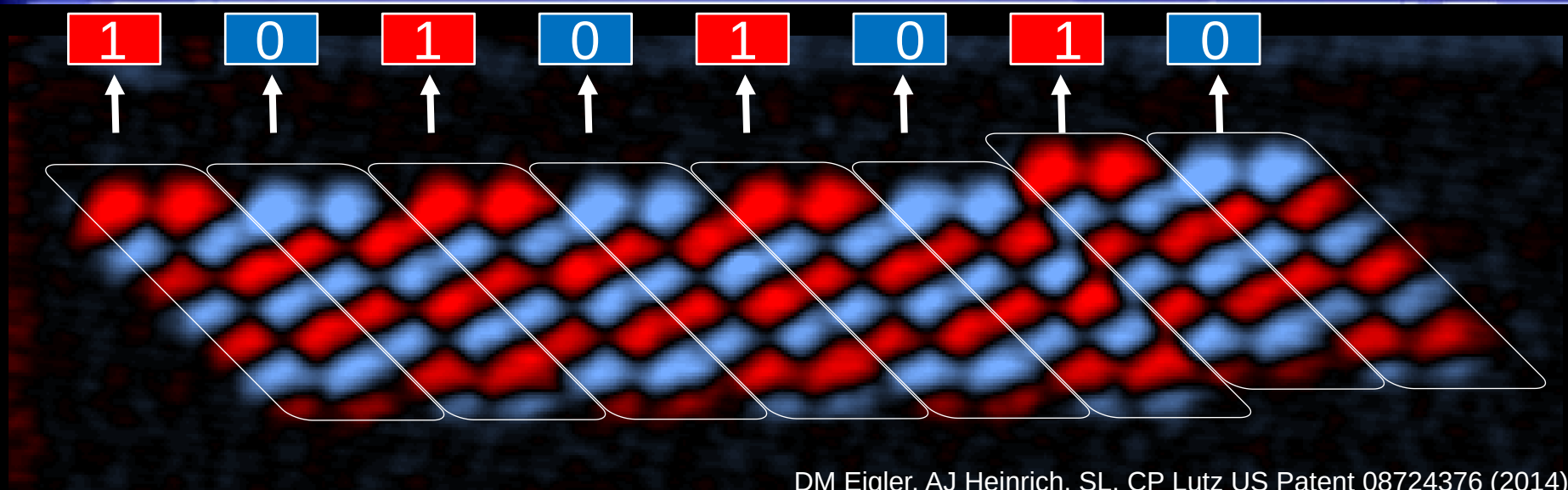




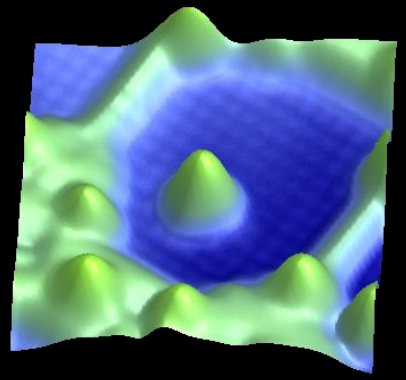
Stability at 0.5K >17h.

SL, S. Baumann, C.P.Lutz, D.M. Eigler, A.J. Heinrich, Science 2012





DM Eigler, AJ Heinrich, SL, CP Lutz US Patent 08724376 (2014)



Functionality in just a few atoms:

Bistable antiferromagnets (8 atoms)
Spin sensing (3 atoms)

Atomic-scale Dynamics

www.fastatoms.de

Thanks!

MPI Structure and Dynamics of Matter, Hamburg

MPI Solid State Research, Stuttgart







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