Excitations and Interactions

B1, B2,
B4, B6, B13N

A7, A9, A12

A10, B5, B8

Materials Design - Synthesis & Modelling

A3, A8, B1,
B2, B4, B6,
B9, B11, B13N

A5, A7, A9,
A12, B3

A10, B5,
B8, B12

Cooperative Phenomena

A3, A8, B1,
B2, B4, B6,
B9, B11, B13N

A5, A7, A9,
A12, B3

A10, B5,
B8, B12

tions & Interactions

New in Excitations and Interactions

- Spin physics is now much deeper integrated into our model systems
- Dynamical aspects now much expanded and strengthened
- Polaronic excitations are studied in a variety of model systems (presented by Michael Fleischhauer)

➔ **We now have much better systems to use tunability**

Excitations and Interactions

- Magnon gases A7 A8
- Spin physics A3 A5 A9 A10 A12
- Quantum magnets A3 A8 B1 B2 B3 B4 B5
- Synthesis B6 B9 B10
- Spectroscopy B8 B11 B12

Excitations and Interactions

Experiment

A7 Collective effects and instabilities of a magnon gas

A9 Ultracold Bose gases with variable interactions

A10 Designing spin-spin interactions in cold ion crystals

A12 Multi-polaron effects with spinless and spinful impurities in a bosonic quantum gas

B1 Interacting magnetic excitations in quantum spin systems – thermodynamic investigations

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B1 Interacting magnetic excitations in quantum spin systems – thermodynamic investigations

Theory

A3 Inhomogeneous quantum phases and dynamics in ultracold gases and hybrid atom-ion systems

A5 Advanced numerical methods for correlated quantum gases

A8 Interacting magnons and critical behaviour of bosons

B3 Correlations in antiferromagnets

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Theory

A3 Inhomogeneous quantum phases and dynamics in ultracold gases and hybrid atom-ion systems
DMFT and variational techniques

A5 Advanced numerical methods for correlated quantum gases
1D and 2D systems at T = 0
strongly correlated systems

A8 Interacting magnons and critical behaviour of bosons
Non-equilibrium dynamics
weakly correlated systems

B3 Correlations in antiferromagnets
Excitations near critical points in boson and spin systems

Excitations and Interactions

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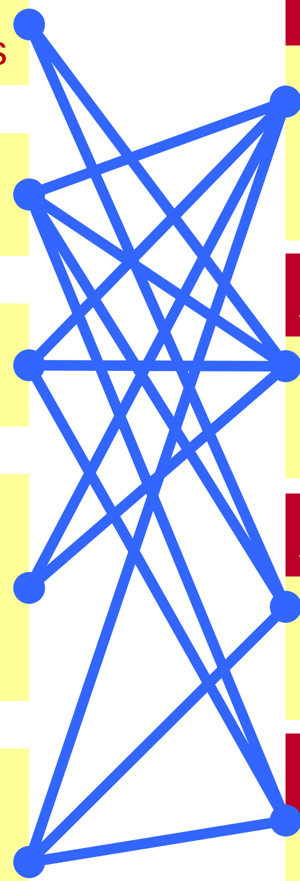
B1 Interacting magnetic exci-tations in quantum spin systems – thermo-dynamic investigations



Theory

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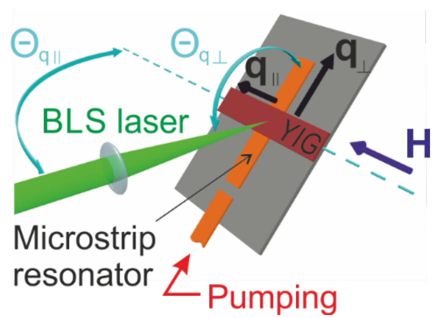
Excitations and Interactions

- Magnon gases **A7** **A8**
- Spin physics **A3** **A5** **A9** **A10** **A12**
- Quantum magnets **A3** **A8** **B1** **B2** **B3** **B4** **B5**
- Synthesis **B6** **B9** **B10**
- Spectroscopy **B8** **B11** **B12**

Magneto-elastic modes and lifetime of magnons in yttrium-iron garnet films

A7 **A8**

Experimental method
Time-, space- and wavevector-resolved BLS spectroscopy of parametrically injected magnons

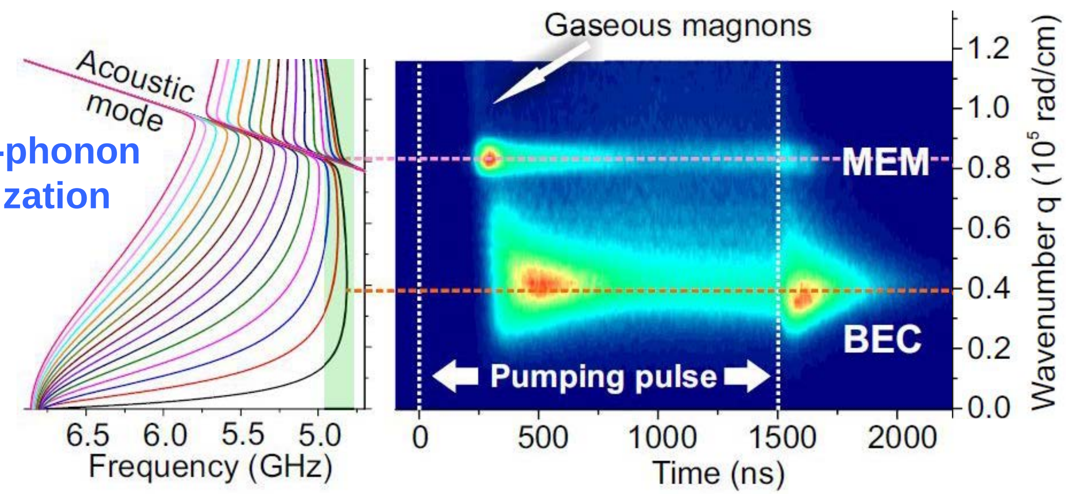


Phonon-magnon spectrum & damping
Phys. Rev. B (2014)

A7 **A8**

Highlight: Condensation of hybridized magnon-phonon states

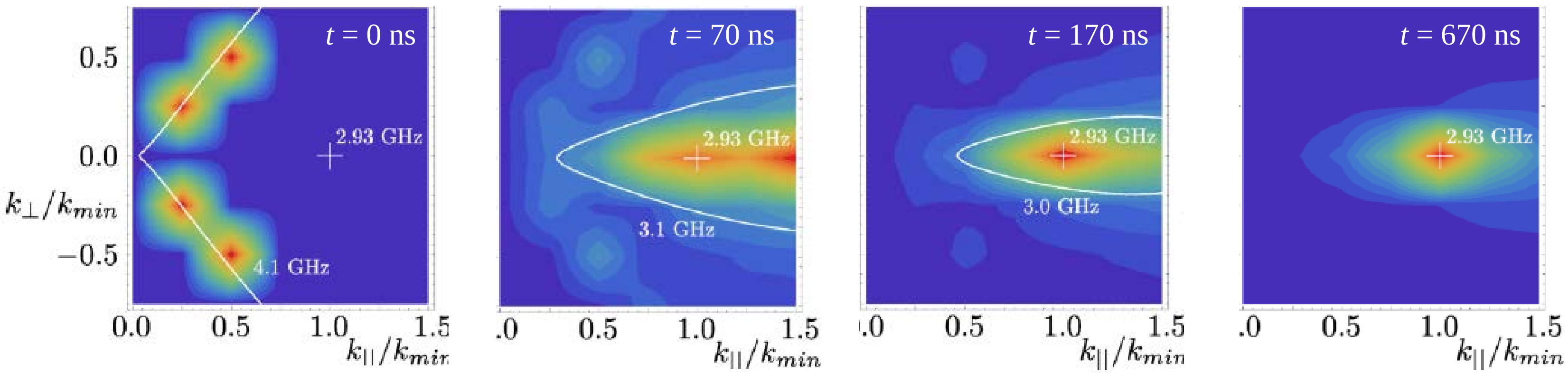
Magnon-phonon hybridization



Magnon gases –thermalization, electric detection

Highlight: Thermalization of the free evolving magnon gas in YIG due to coupling to a phonon bath

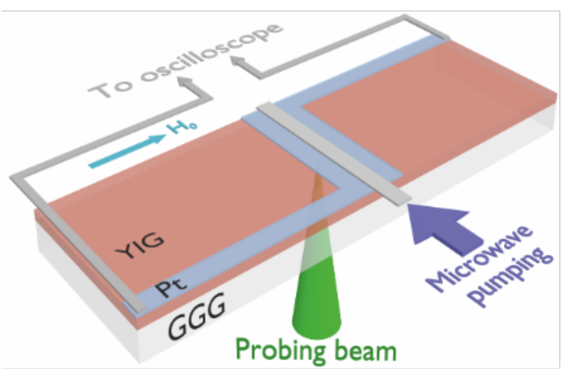
A8

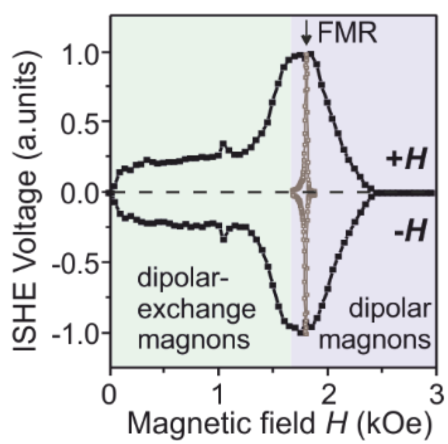


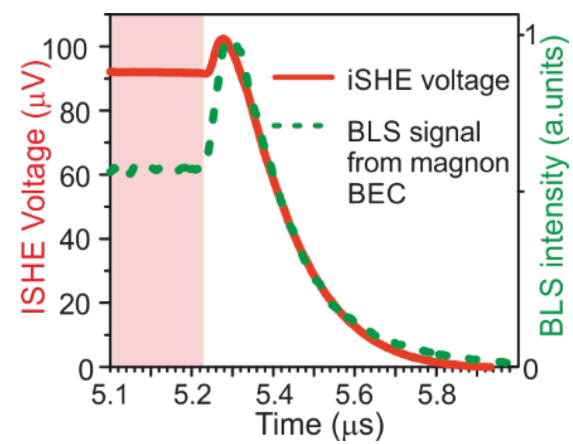
Phys. Rev. B **86**, 184417 (2012)

Highlight: Electric detection of magnon gas dynamics and its coherency

A7





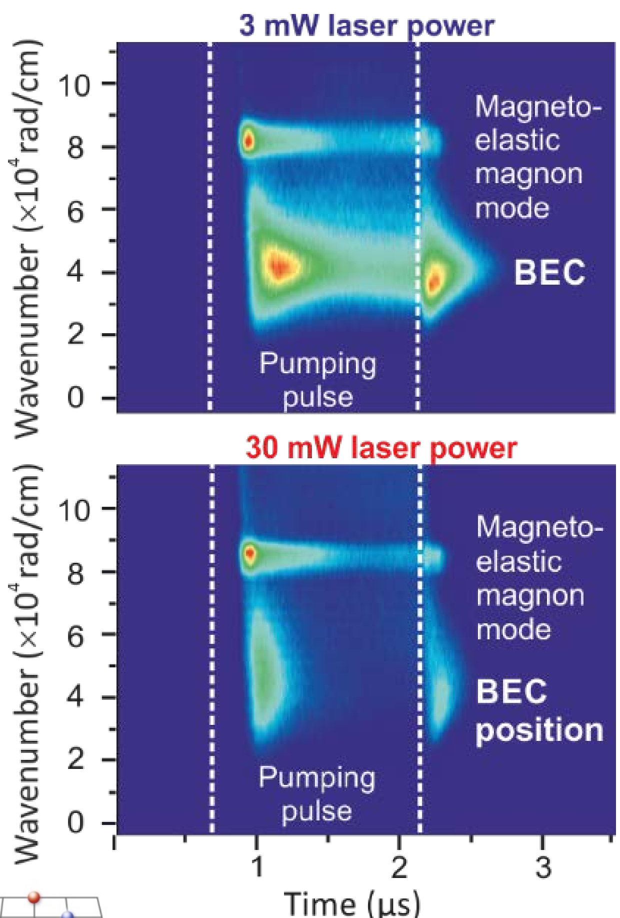


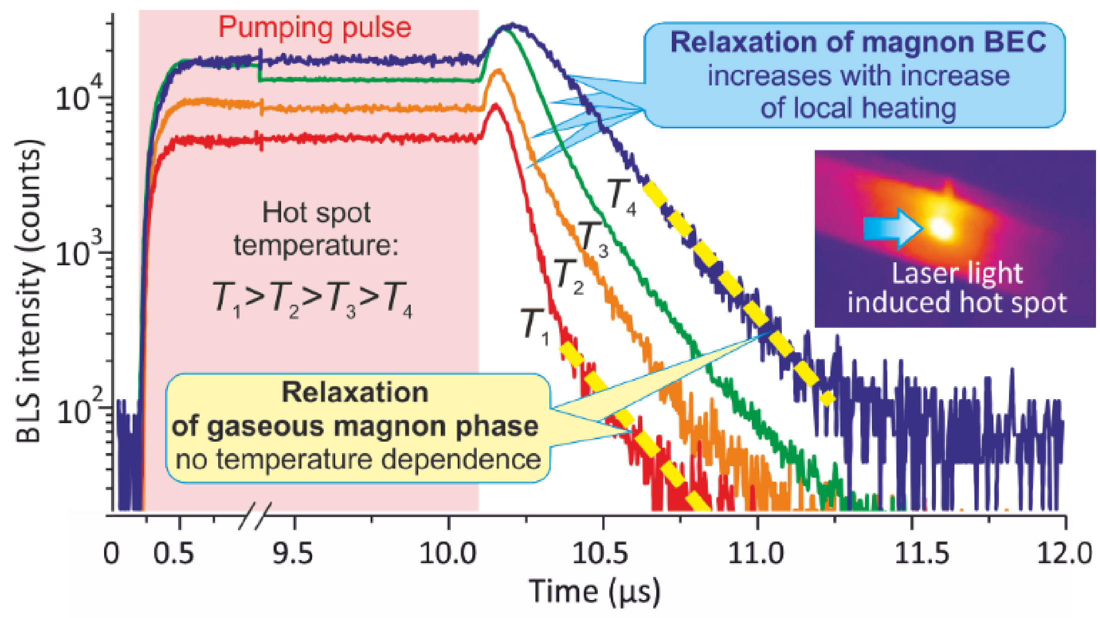
Magnon gases – evidence of a supercurrent

A7

Evolution of the magnon BEC, gaseous magnon phase, and magneto-elastic mode in a local temperature gradient

Next: Magnon Supercurrent – jointly with **A8**





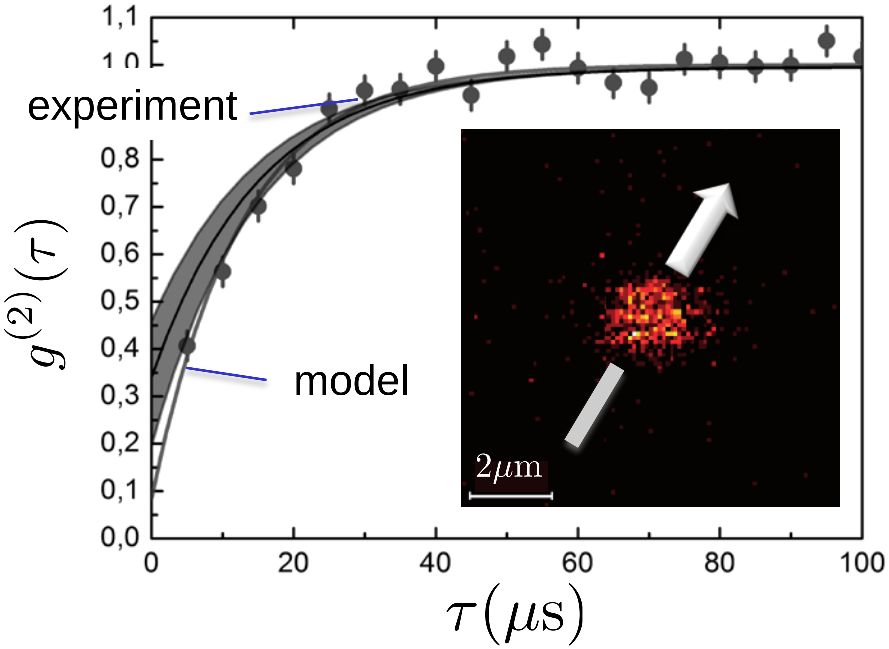
Fast relaxation of the magnon BEC due to the magnon leakage caused by a phase induced **magnon supercurrent**

Excitations and Interactions

- Magnon gases A7 A8
- Spin physics A3 A5 A9 A10 A12
- Quantum magnets A3 A8 B1 B2 B3 B4 B5
- Synthesis B6 B9 B10
- Spectroscopy B8 B11 B12

Excitation and dynamics of a Rydberg super-atom

Highlight: preparation, characterization and theoretical understanding of a mesoscopic superatom



Nature Physics 2015

A5 **A9**

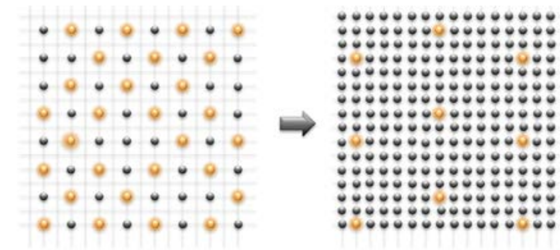
- Superatom = ingredient to study spin physics with long-range interactions **A9**
  - first preparation of isolated superatom, only one excitation $g^{(2)}(0) \rightarrow 0.08 \pm 0.06$ (strong anti-bunching due to Rydberg blockade)
  - quantitative theoretical modeling and understanding **A5**

Rydberg gases in optical lattices

Competing ordered structures in effective lattices

- preparation of lattice structures with varying lattice spacing by e-beam depletion
- analysis of structural transitions

A5 A9

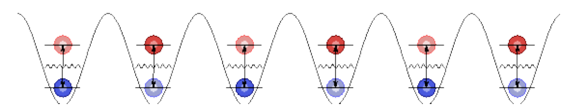


cubic – triangular transition

Crystalline and magnetic order in lattice gases

- crystalline, supersolid and magnetic phases & dynamics of their formation

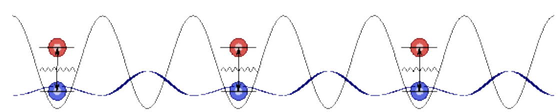
A3



canted Ising antiferromagnet

- Including kinetic energy beyond „frozen Rydberg gas“

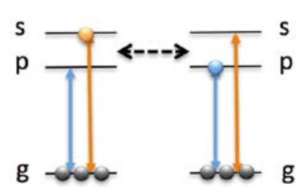
A3 A5

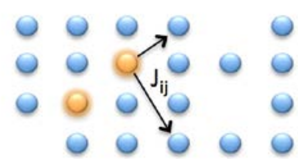


supersolid

- excitation (s-p) transport in lattice gases

A5 A9





Engineering interactions mediated by a BEC

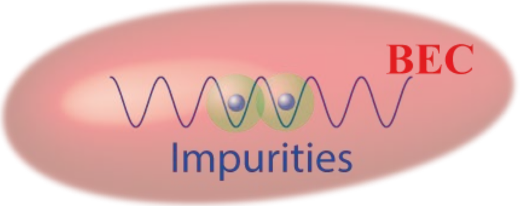
Bath mediated interaction: Beyond the single polaron description

- Characterize mediated impurity-impurity interaction
- Study impurity dynamics and properties in the strongly interacting regime

A12

A5

A3

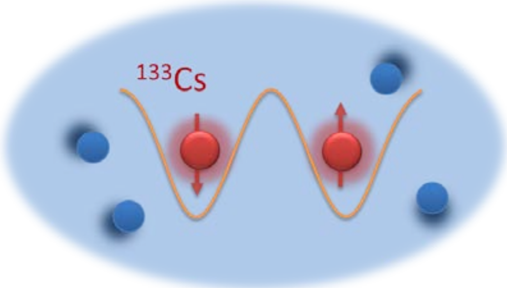


Bath-mediated interaction

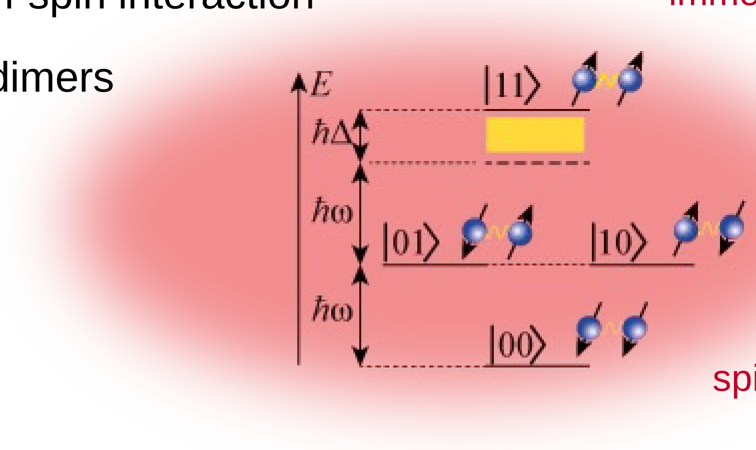
Effective spin-spin interaction between two impurities

- Exploit hyperfine ground states as quasi-spin
- Study spin-dependent impurity-bath interaction
- Induce and control effective spin-spin interaction
- A model system for interacting dimers

A12 A3



Quasi-spin ½ Cs impurity immersed in Rb bath



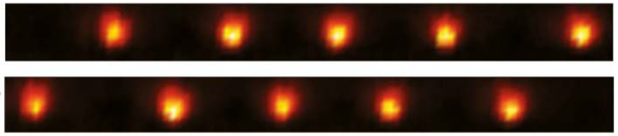
Bath mediated spin-spin interaction

Designing spin-spin interactions in ion crystals

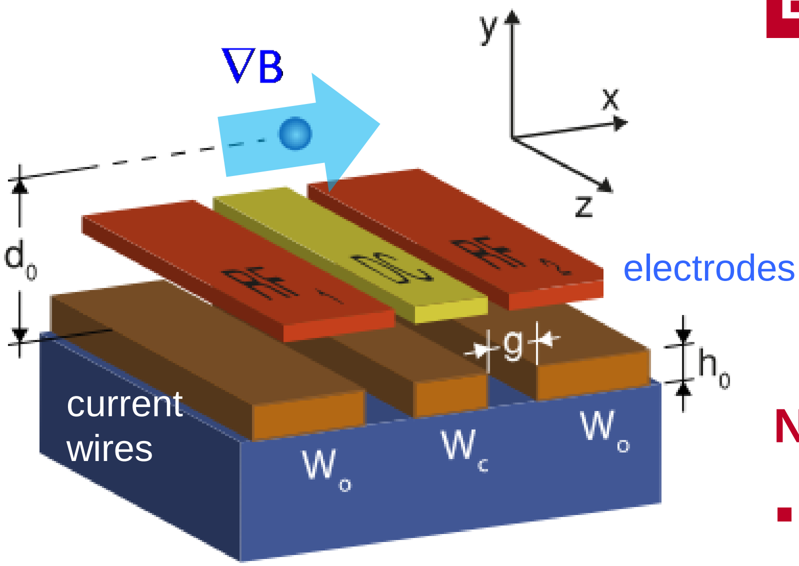
Advantages of trapped ion crystals A10

- linear or two-dimensional structures available
- Strong and long range interactions, tailored by design of vibrational modes A3
- trigonal symmetry allows for spin-frustration B1 B3

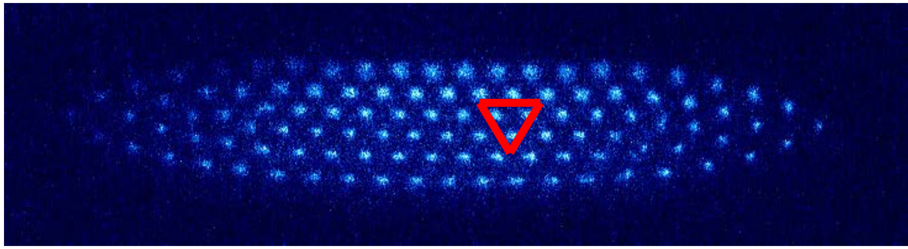
$$H = \sum_{j<i} J_{ij}\sigma_x^{(i)}\sigma_x^{(j)} - B\sum_i \sigma_y^{(i)}$$



Islam et al., Science **340**, 583 (2013)



novel chip trap, realized in Mainz



Planar crystal with 100 ions

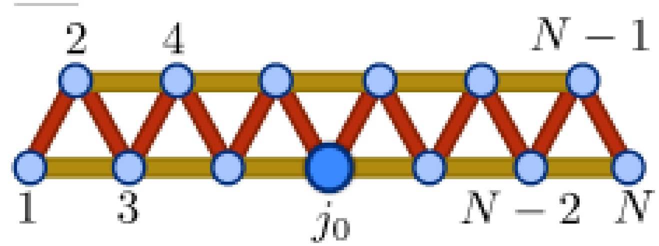
Next: Spin-dependent tailored forces

- optical dipole force in standing wave
- Stern-Gerlach force on ion spins in gradient B
- Implementation in micro-structured planar trap

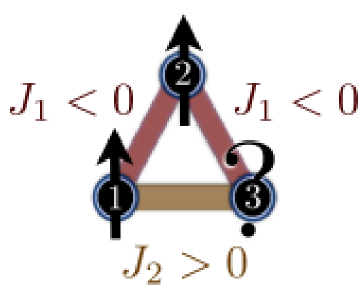
Ladder spin system in a zigzag ion crystal

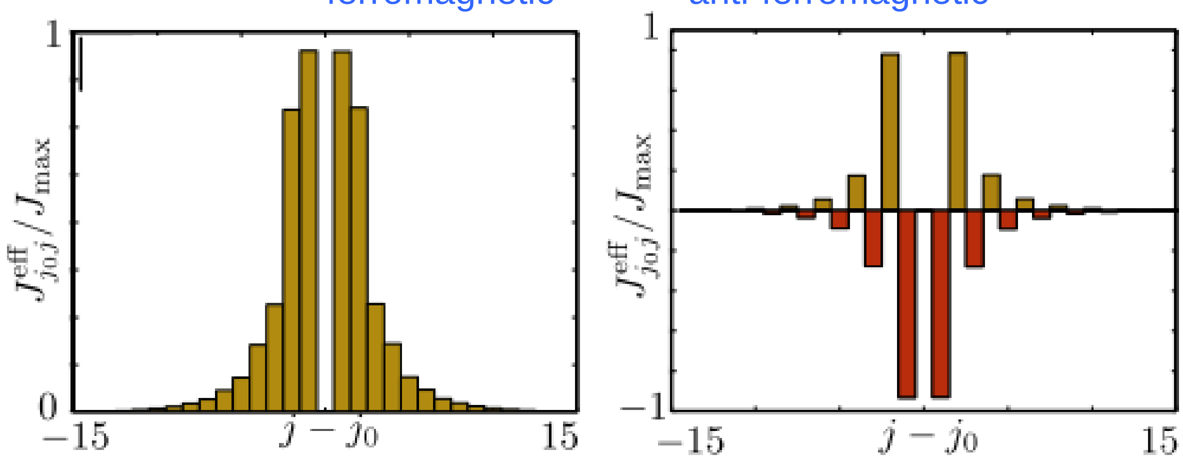
- Controlled sign-change of J^{eff} **A10**
- Effective Hamiltonian

$$H_{\text{eff}} = \sum_{j \neq k} J^{\text{eff}}_{jk} \sigma^z_j \sigma^z_k - h \sum_j \sigma^x_j$$

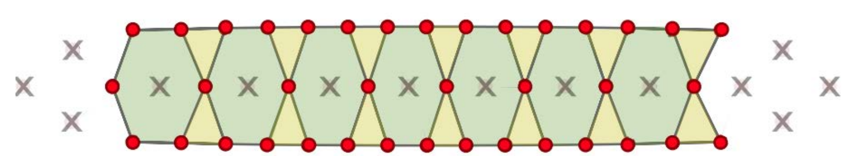


Ladder spin system





- Complex phase diagram in frustrated Ising model: paramagnetic, ferro and anti-ferromagnetic, dipolar and floating phase
- Simulation of effects of tunable frustration in complex geometric structures **B3**



Kagome system

Excitations and Interactions

- Magnon gases A7 A8
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- Synthesis B6 B9 B10
- Spectroscopy B8 B11 B12

Quantum magnets

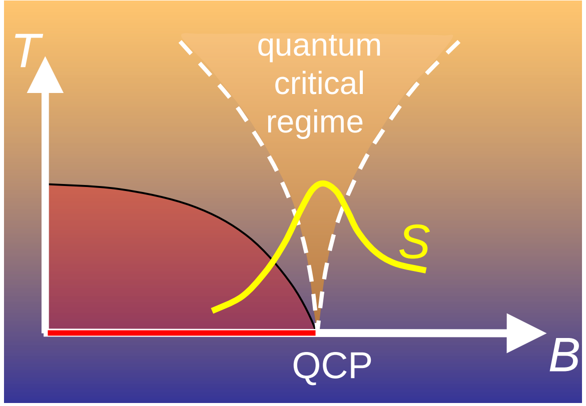
Novel interaction-driven cooling processes in ultra cold quantum gases and solid state systems **B1**

Samples prepared in **B4**

solid state systems:

- accumulation of entropy around a *B*-induced quantum-critical point
  ➔ efficient magnetic cooling

Proc. Natl. Acad. Sci. USA (2011)



Int. J. Mod. Phys. (2014)

A3 **B4**

Theoretical aspects of magnetic cooling

B3 **A8**

- proof of principle:
  ➔ antiferromagnetic S = ½ Heisenberg spin chain (AFHC)

- Cooling efficiency: paramagnet: ~10%; AFHC: ~ 25%; 2d frustrated afm: ~ 50%

Next: 2d frustrated quantum magnets such as Cs_2CuCl_4

Phys. Status Solidi B **250** (2013)

Quantum magnets

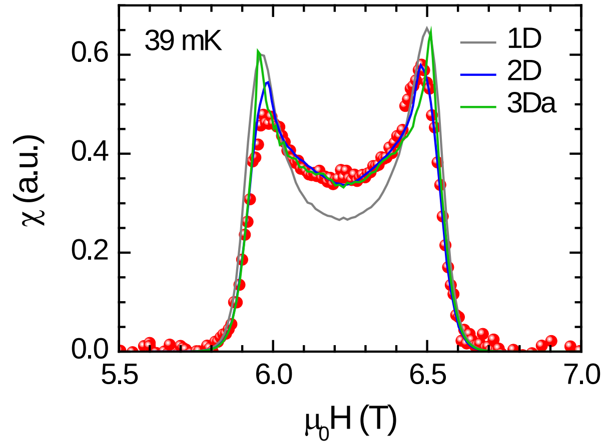
Coupled S=1/2 dimer systems: effects of 2D excitations

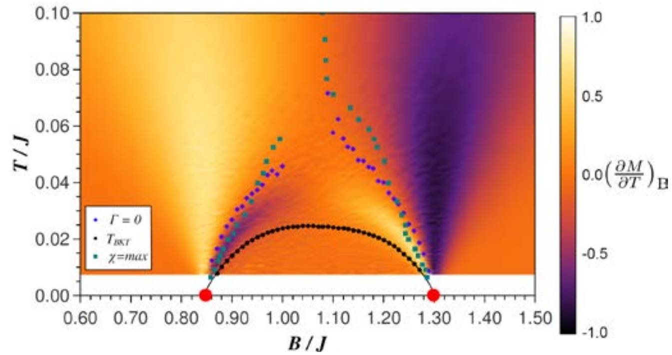
Nature Comm. **5**, 5169 (2014)
with S. Wessel, Aachen

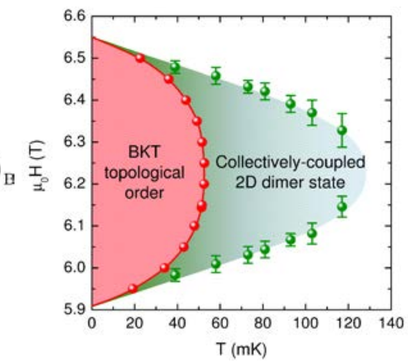
B1 **B2** **B5**

- Cu-coordination polymer (TK91)
- excitations reveal a distinctly 2D character
- Berezinskii-Kosterlitz-Thouless scenario
  - occurrence of vortex and anti-vortex excitations
- theory of the critical behavior and the magnetocaloric effect

arXiv:1412.0266 **B3** **A8**







Next:

- new materials with extented range of field induced order (stable organic radicals) **B5**
- Simulations on coupled clusters **B3**