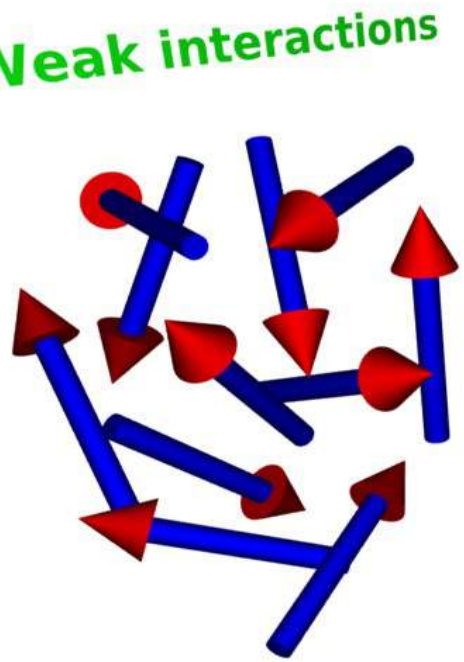
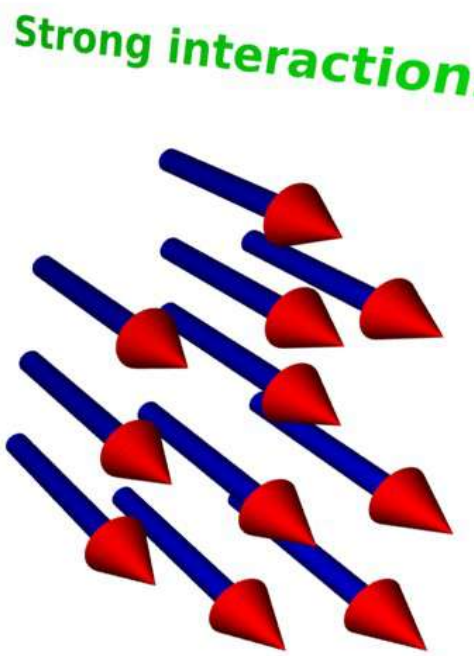
A repulsive atomic gas on the border of itinerant ferromagnetism





Gareth Conduit[1,2] , Ben Simons[3] & Ehud Altman[1]

1. Weizmann Institute, 2. Ben Gurion University, 3. University of Cambridge

G.J. Conduit & B.D. Simons, Phys. Rev. A **79**, 053606 (2009)

G.J. Conduit, A.G. Green & B.D. Simons, Phys. Rev. Lett. **103**, 207201 (2009)

G.J. Conduit & B.D. Simons, Phys. Rev. Lett. **103**, 200403 (2009)

G.J Conduit & E. Altman, arXiv: 0911.2839

Itinerant ferromagnetism in cold atom gases

- Use two ^{6}Li states to represent pseudo up and down-spin electrons
- Effective Hamiltonian

  $H = \sum_{k\sigma} \varepsilon_k n_\sigma(\varepsilon_k) + gN_\uparrow N_\downarrow$

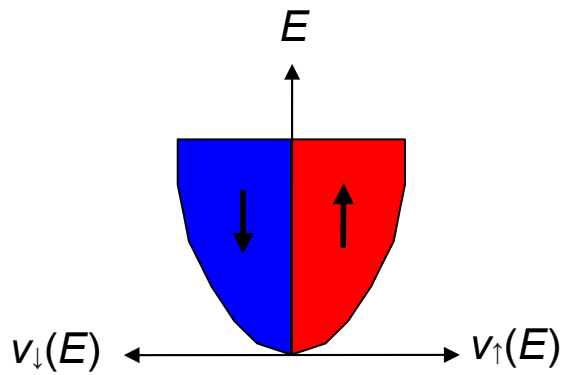
- A ΔE shift in the Fermi surface causes:

  (1) Kinetic energy increase of $\frac{1}{2}\nu\Delta E^2$

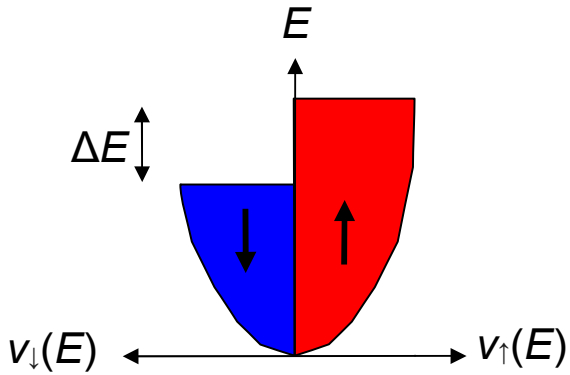
  (2) Reduction of repulsion of $-\frac{1}{2}g\nu^2\Delta E^2$

- Total energy shift is $\frac{1}{2}\nu\Delta E^2(1-g\nu)$ so a ferromagnetic transition occurs if $g\nu>1$

Not magnetised



Partially magnetised

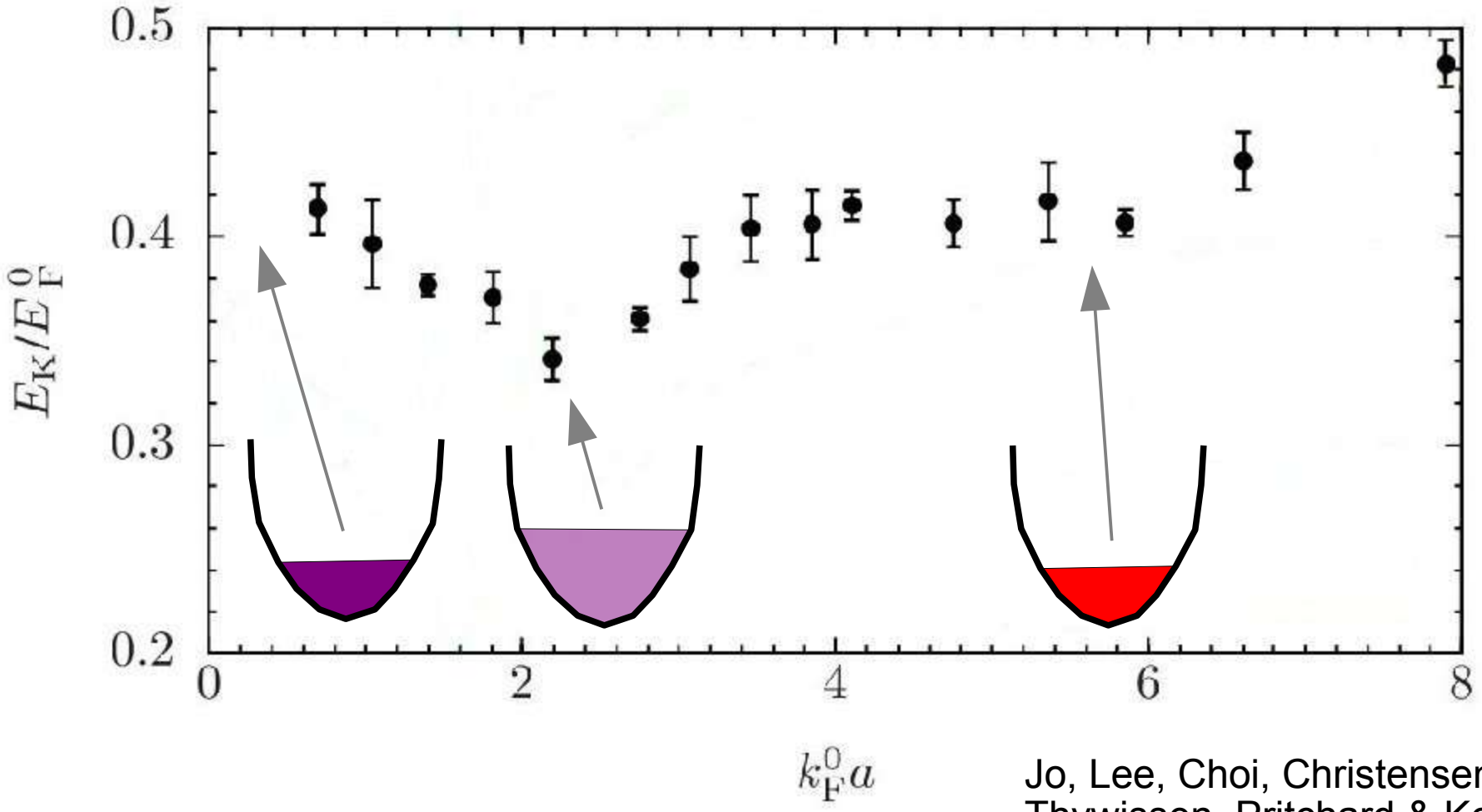


G.J. Conduit & B.D. Simons, Phys. Rev. A **79**, 053606 (2009)

Jo, Lee, Choi, Christensen, Kim, Thywissen, Pritchard & Ketterle, Science **325**, 1521 (2009)

Experimental evidence for ferromagnetism

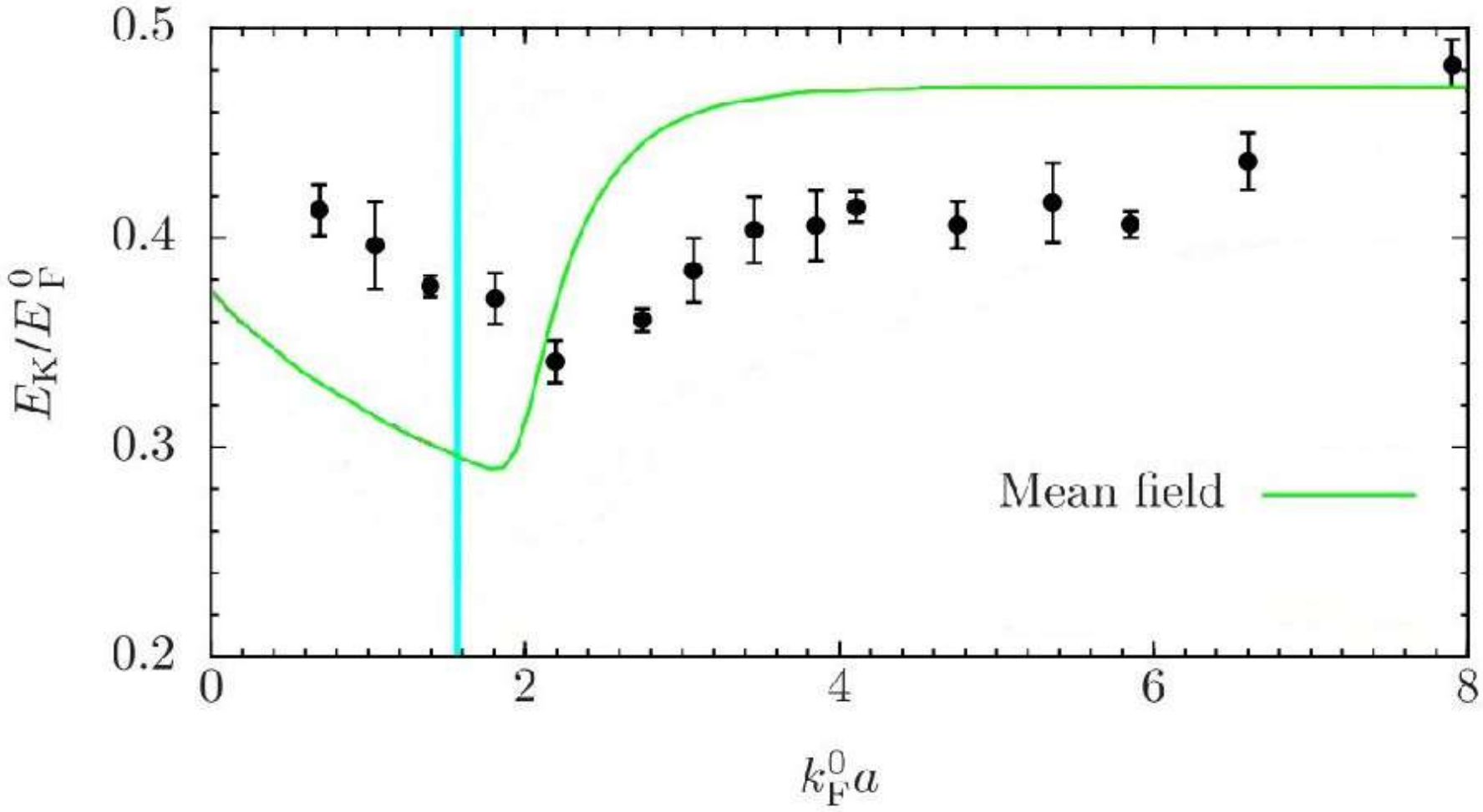
- Experimental points display same qualitative behavior but transition at $k_F a$=2.2



Jo, Lee, Choi, Christensen, Kim, Thywissen, Pritchard & Ketterle, Science **325**, 1521 (2009)

Mean-field theory for ferromagnetism

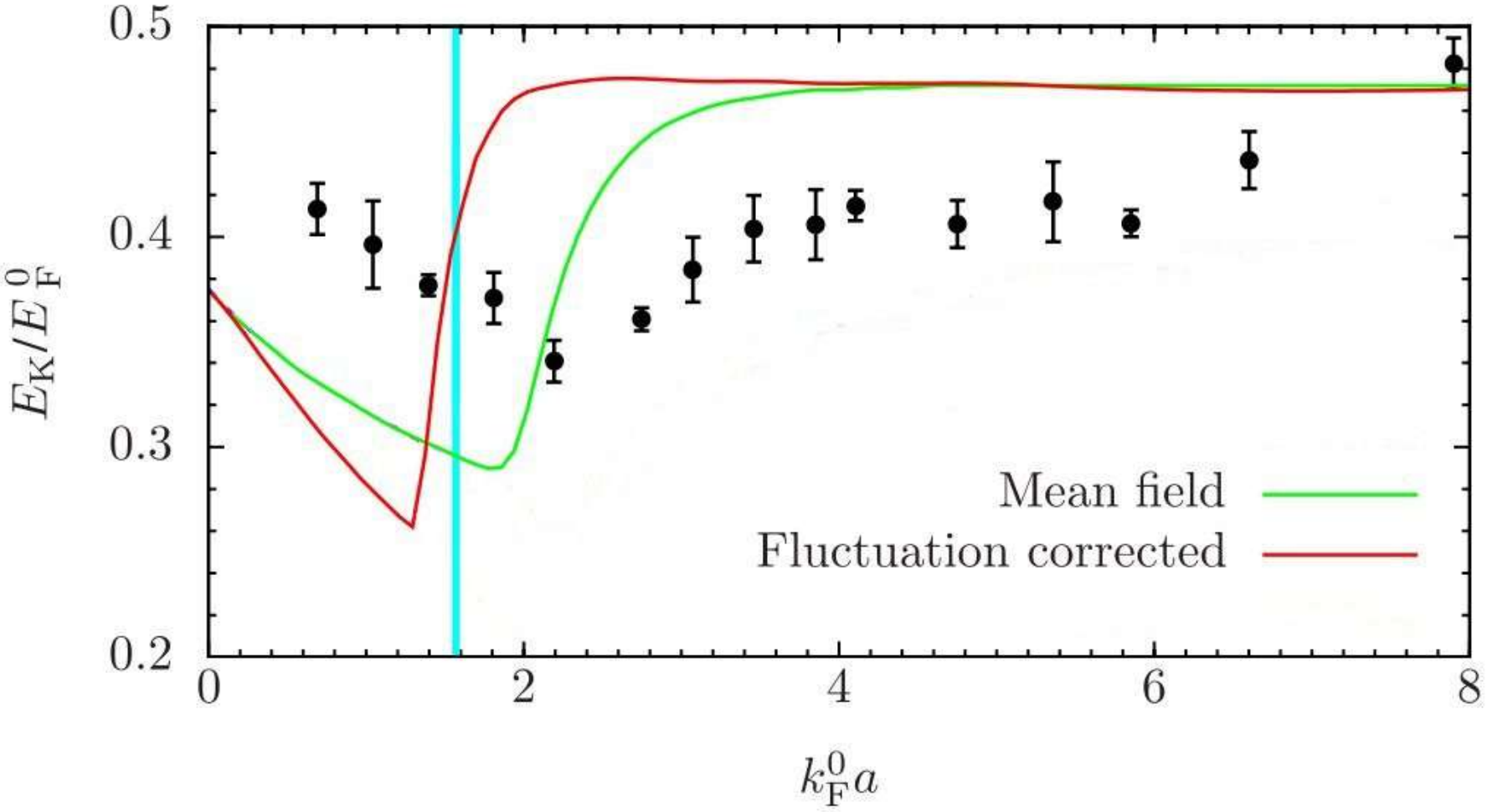
- The Stoner model predicts[1] a minimum in the kinetic energy at $k_F a$=1.8



[1]LeBlanc *et al.*, PRA **80**, 013607 (2009) & Conduit & Simons, PRL **103**, 200403 (2009)

Fluctuation corrections

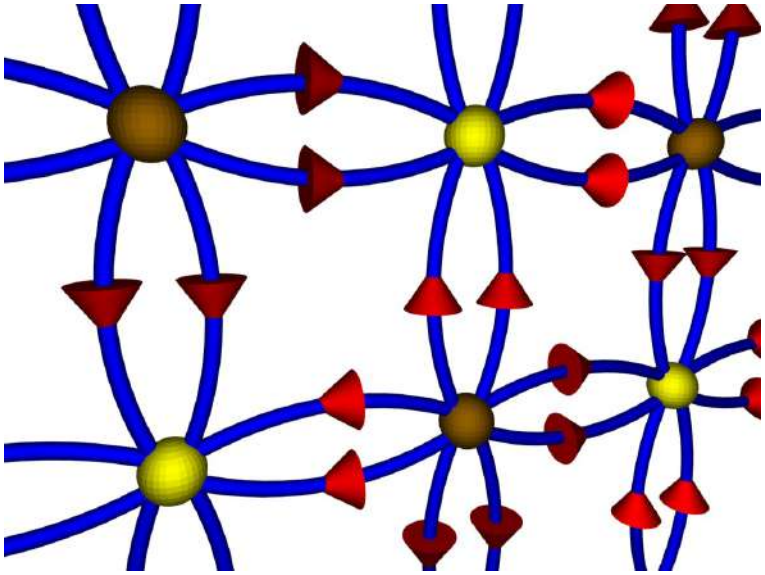
- Extend theory through fluctuation corrections



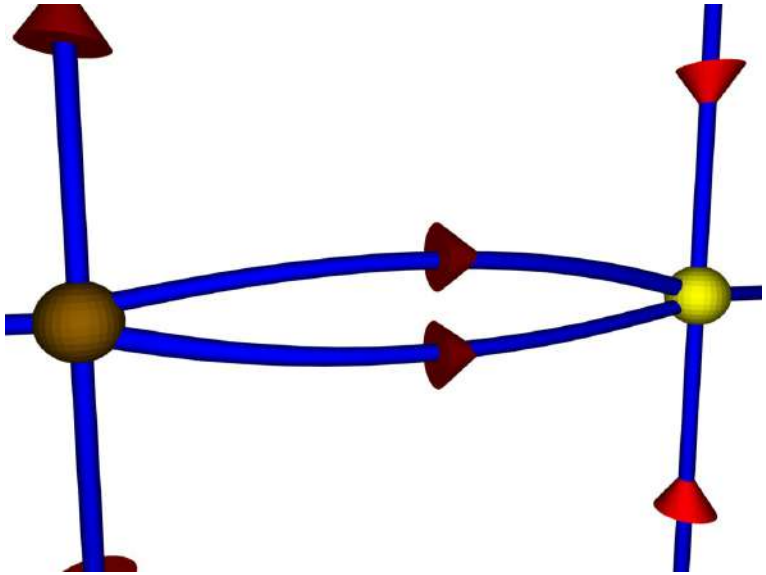
Conduit & Simons, Phys. Rev. A **79**, 053606 (2009) & Conduit & Simons, PRL **103**, 200403 (2009)

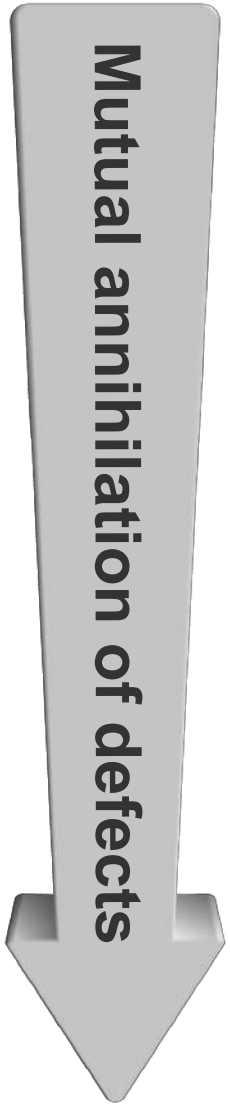
Condensation of topological defects

- Defects freeze out from disordered state



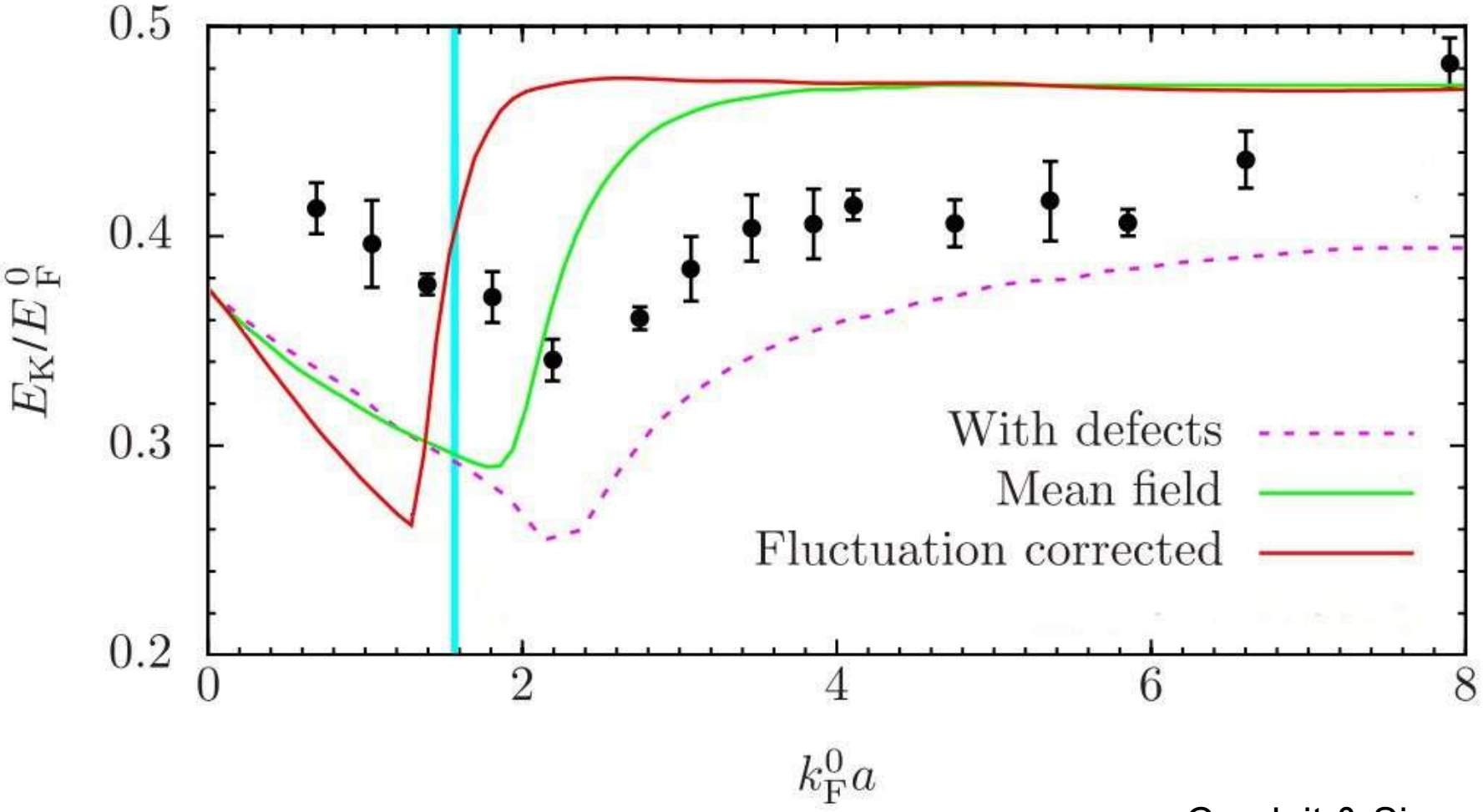
- Defect annihilation hinders the formation of the ferromagnetic phase thus raising the required interaction strength
- Defect radius $L \sim t^{1/2}$ [Bray, Adv. Phys. **43**, 357 (1994)]





Condensation of topological defects

- Condensation of defects inhibits the transition

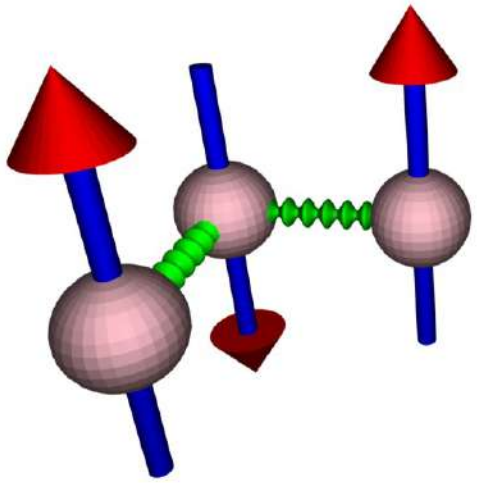


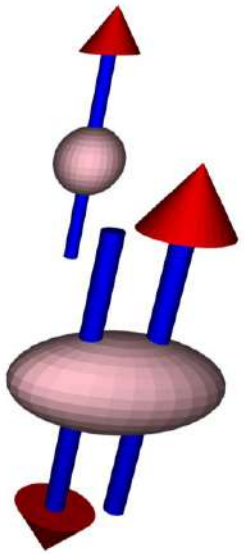
Conduit & Simons, PRL **103**, 200403 (2009)

Conclusions

- Mean-field theory provides a reasonable qualitative description of the transition
- Discrepancy in the interaction strength could be accounted for by the mutual annihilation of defects inhibiting the formation of the ferromagnetic phase
- Work ongoing on the renormalization of interaction strength due to three-body atom loss [Conduit & Altman, arXiv: 0911.2839]

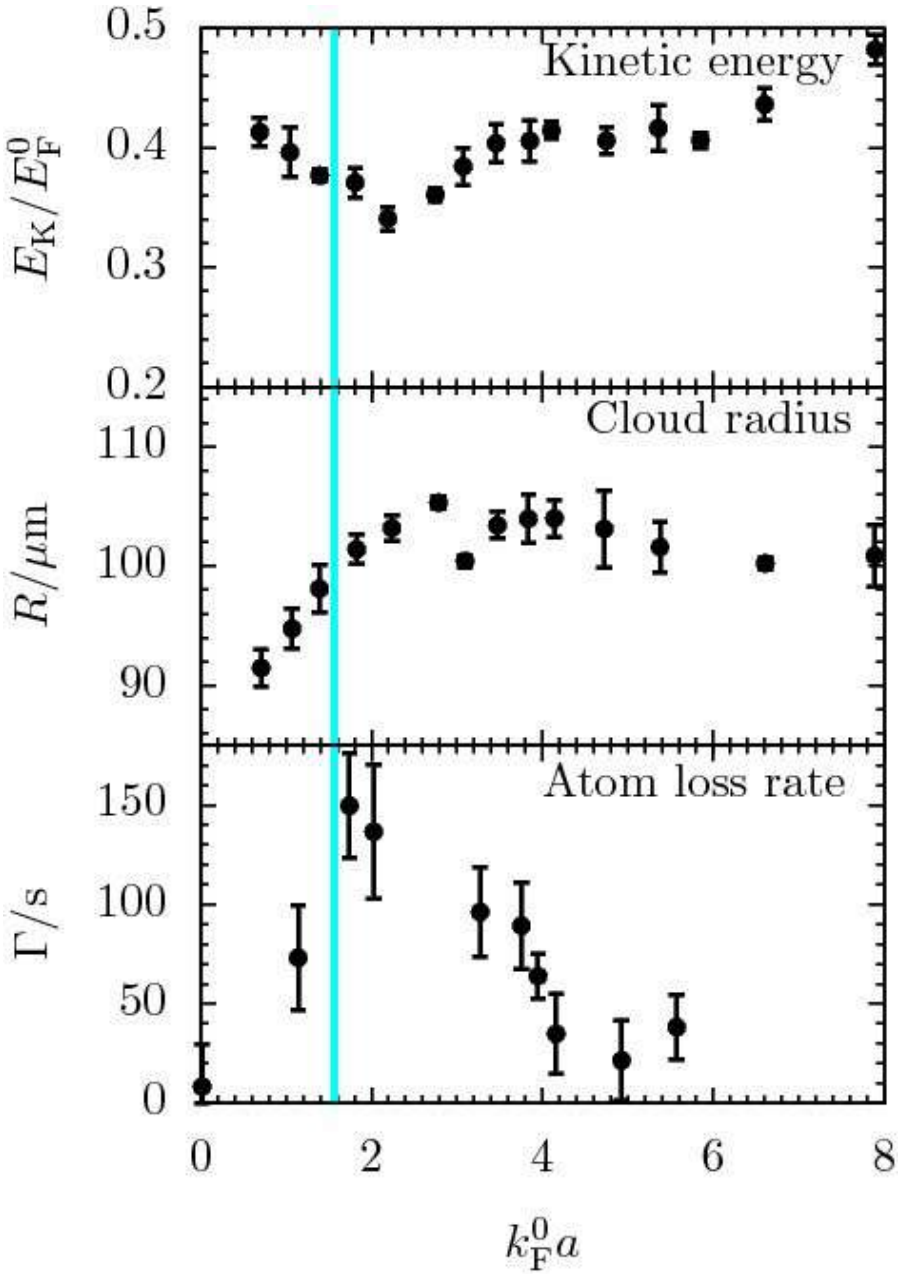
Three-body interaction





Molecular state lost

Key experimental signatures



Jo, Lee, Choi, Christensen, Kim, Thywissen, Pritchard & Ketterle, Science **325**, 1521 (2009)