Instability of a spin spiral to probe the Stoner transition

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INTRODUCTION

The Ketterle group at MIT presented the first tentative evidence for ferromagnetic phenomena in a cold atom gas [1]. To circumvent the many-body losses we propose [2] to study the dynamical evolution of a spin spiral. In this poster we:

- Develop the formalism to study the dynamical evolution of a spin spiral
- Propose how the spin spiral evolution could be tracked in experiments
- Reveal the characteristic behavior over long time scales
- Demonstrate that the spin spiral could allow experimentalists to study the Stoner instability with dramatically reduced losses

The proposed experimental setup is shown in Fig. 1. A fully polarized state of fermionic atoms is prepared and a normal magnetic field gradient forms the spin spiral with wave vector $Q_y=(\mu_B g_J t/\hbar)\mathrm{d}B_x/\mathrm{d}t$. The twist rate is independent of spin stiffness and interactions between the atoms so the spiral can be formed in the presence of the Feshbach field.

The repulsive interactions are then ramped up and the evolution of the spiral tracked. The system should have dramatically reduced losses as locally it is almost fully polarized.

The evolution of the spin spiral could be monitored by *in situ* phase contrast imaging or Bragg spectroscopy.

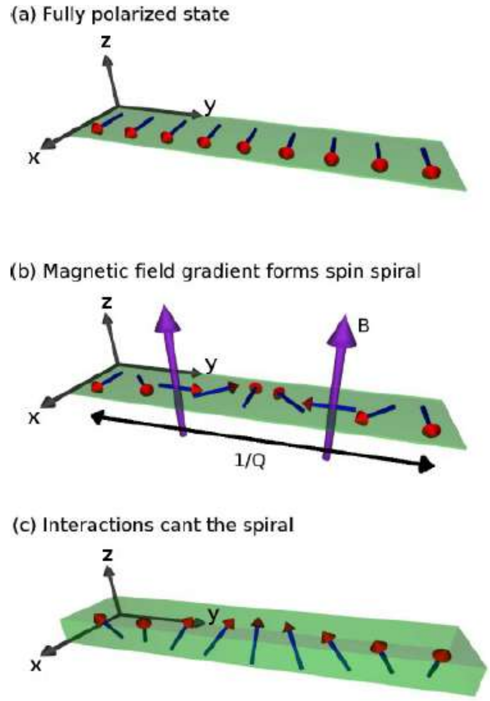

Fig. 1. The experimental protocol: (a) the gas is set up in the fully polarized phase, (b) a normal magnetic field gradient forms the spin spiral, and (c) the spiral evolves under repulsive interactions

DYNAMICAL EVOLUTION

The Hamiltonian is

$$\hat{H}=\sum_{k\sigma}\epsilon_k c^\dagger_{k\sigma}c_{k\sigma}+g\sum_{kk'q}c^\dagger_{k\uparrow}c^\dagger_{k'+q\downarrow}c_{k'+q\downarrow}c_{k'\uparrow}$$

At short times $\Omega t \ll 1$ the spin spiral evolves with a growth rate of the mode k of

$$\Omega=\pm\left(\frac{1}{2}-\frac{2^{2/3}3}{5k_F a}\right)k\sqrt{Q^2-k^2}$$

The spiral evolution has critical slowing at $k_F a\approx 1$ and peak growth rate at $k=Q/\sqrt{2}$.

An evolved spin spiral contains new plane waves that themselves evolve, which we further analyze using second order theory. This results in the breakdown of the critical slowing and asymmetric growth either side of the critical interaction strength.

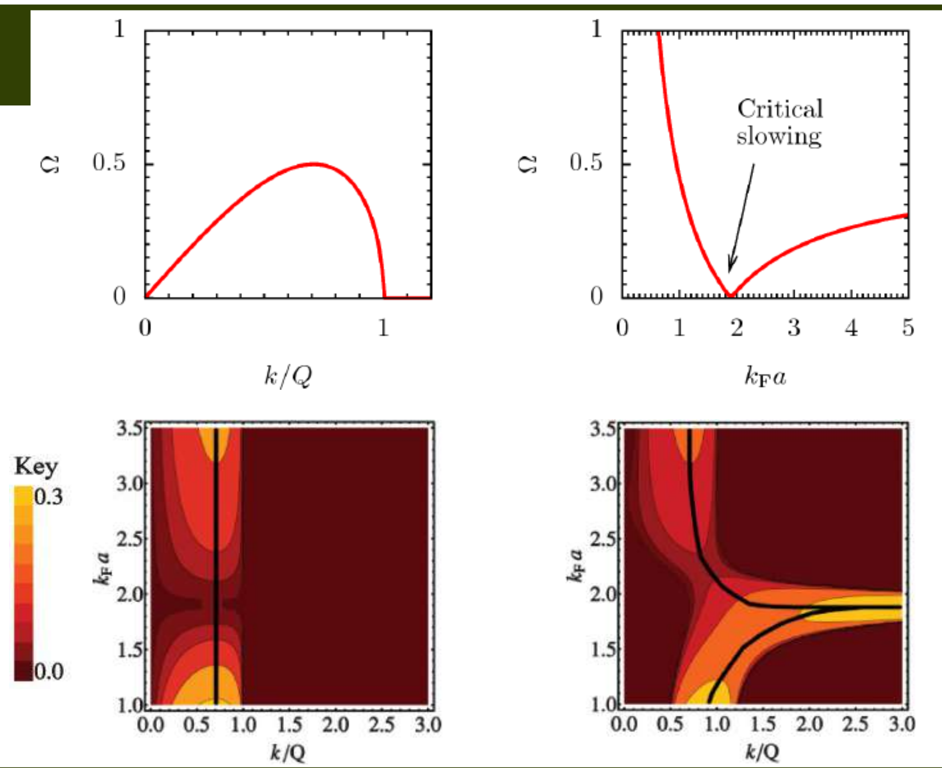

Fig. 2. *Upper*: The domain growth rate Ω as a function of wave vector k and interaction strength $k_F a$. *Lower*: The domain growth rate at small times (left) and long time (right).

ATOM LOSS

The three body loss rate

$$\Gamma=\Gamma_0(k_F a)^6 n_\uparrow n_\downarrow(n_\uparrow+n_\downarrow)$$

is significantly reduced by the spin spiral. This could allow the full features of the critical slowing phenomenon to be revealed in experiments.

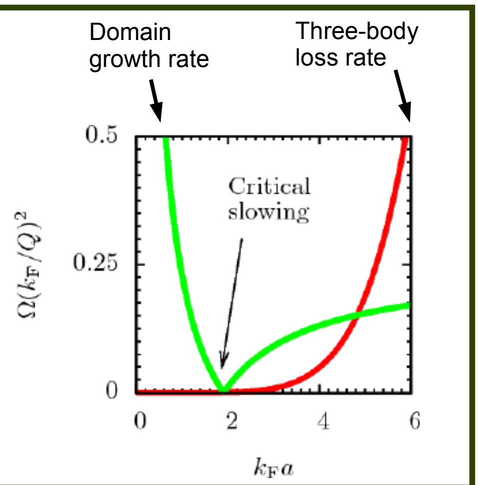

Fig. 3. Comparing the growth rate of the magnetic domains (green) with the three-body loss rate (red).

CONCLUSIONS

- The dynamical evolution of a spin spiral reveals signatures of the Stoner instability
- The spin spiral could allow experimentalists to study the Stoner instability with dramatically reduced many-body losses

[1] G.-B. Jo *et al.*, Science **325**, 1521 (2009)

[2] G.J. Conduit & E. Altman, PRA **82**, 043603 (2010)