Itinerant ferromagnetism in a Fermi gas with mass imbalance

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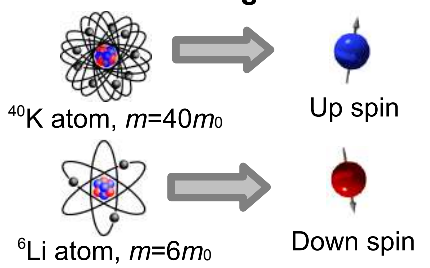
INTRODUCTION

The Ketterle group at MIT have presented the first evidence for ferromagnetic phenomena in a cold atom gas [1]. However, there was a significant atom loss process that could drive the formation of alternative strongly correlated states [2] with similar experimental signatures. It is therefore important to study different realizations of the ferromagnetic state with novel experimental signatures so as to resolve the outstanding questions over the original results. We find that [3] introducing a mass imbalance offers investigators new experimental signatures, and reduces the three-body losses that hinder the formation of the putative ferromagnetic state [4].

The MIT experiment

The results in Fig. 1 show that with increasing repulsive interactions atoms are forced apart so their density drops and therefore their kinetic energy falls. At the ferromagnetic transition ($k_F a$~2) the atoms enter the same Fermi surface so kinetic energy increases. Atom loss $(k_F a)^6 n_\uparrow n_\downarrow (n_\uparrow + n_\downarrow)$ rises before the transition as $(k_F a)^6$, and in the ferromagnetic state falls as $n_\uparrow n_\downarrow \rightarrow 0$.

Mass imbalanced generalization



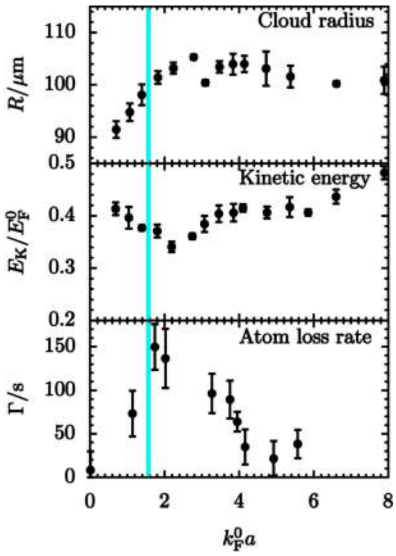


Fig. 1. MIT experimental evidence of the ferromagnetic transition for an equal mass Fermi gas in a harmonic trap.

NEW EXPERIMENTAL SIGNATURES FROM MASS IMBALANCE

LARGER DOMAINS

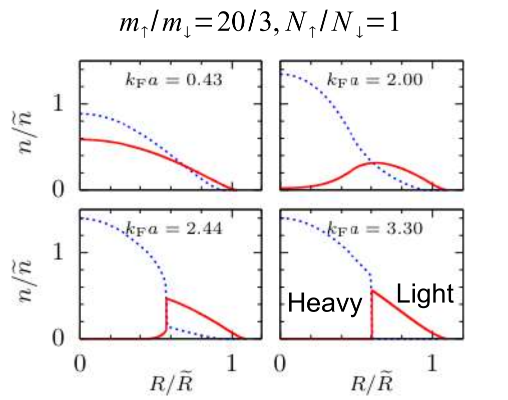


Fig. 2. In a mass imbalanced gas, the heavier species congregates at the center of the trap potential. This may be visible using density contrast imaging.

REDUCED LOSSES

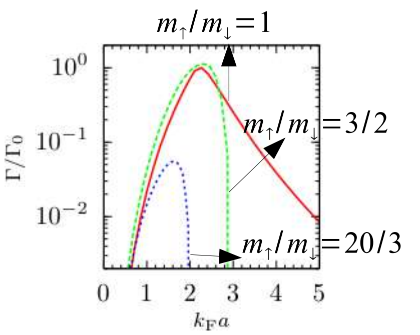


Fig. 3. For a population balanced ^{6}Li-^{40}K mixture, the peak loss rate is reduced by a factor of ~20, and the rate of domain growth reduced by ~5 relative to a mass balanced gas. Therefore for the same net loss the domains in a mass imbalanced gas can undergo ~4 times the growth.

TWO LOSS RATE MAXIMA

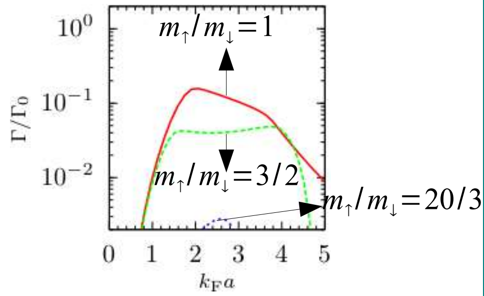


Fig. 4. A double maximum appears in loss rate for large magnetization m=0.95. Again the ^{6}Li-^{40}K peak loss rate is heavily suppressed compared to the mass balanced rate.

NON-MONOTONIC CLOUD GROWTH

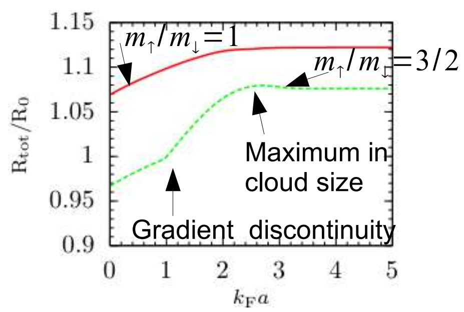


Fig. 5. For sufficiently large magnetization, a gradient discontinuity appears in the cloud size. Generically for mass imbalance, a local maximum also develops.

CONCLUSIONS

- Mass imbalance leads to a significant reduction in the three-body losses that hinder the formation of a putative ferromagnetic state in the ^{6}Li-^{40}K case. New experimental signatures include:
- The formation of larger domains within a harmonic trap.
- A double maximum in loss rate.
- Non-monotonic dependence of cloud size on interaction strength.

REFERENCES

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

[2] D. Pekker, M. Babadi, R. Sensarma, N. Zinner, L. Pollet, M.W. Zwierlein, and E. Demler, Phys. Rev. Lett. **106**, 050402 (2011).

[3] C. W. von Keyserlingk and G. J. Conduit, Phys. Rev. A **83**, 053625 (2011).

[4] D. S. Petrov, Phys. Rev. A **67**, 010703(R) (2003).

ACKNOWLEDGMENTS

C.V.K. acknowledges the financial support of the EPSRC.