Quasi Two-Dimensional ^{6}Li Fermi gas

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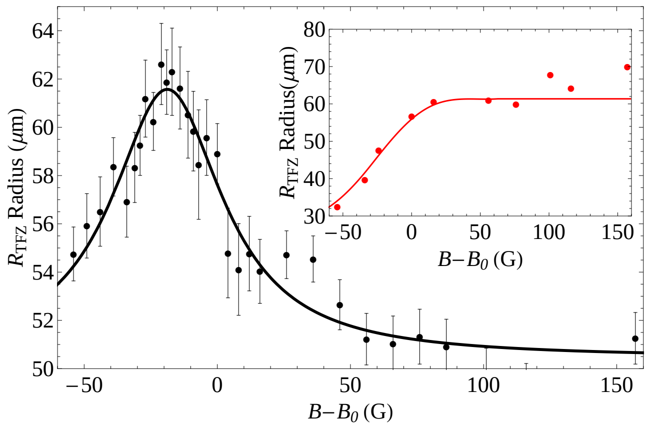
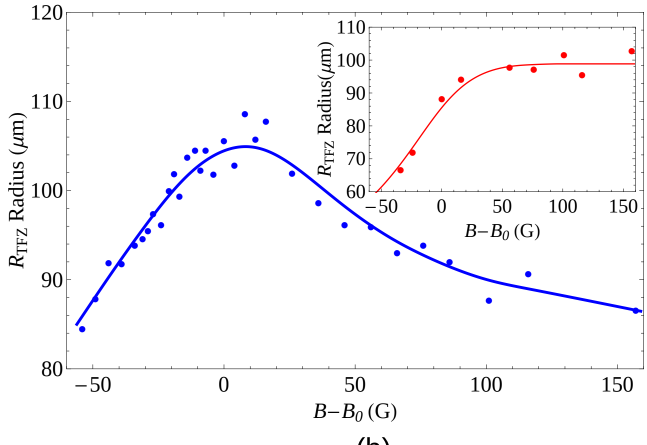
Two-dimensional Fermi gases can behave in surprisingly different ways from their three-dimensional counterparts. This becomes particularly important for a two-component Fermi gas in the Bose-Einstein condensate (BEC) to Bardeen-Cooper-Schrieffer (BCS) crossover region, where the 3D scattering length is widely tunable. In 2D, bound states can exist even on the BCS side of the Feshbach resonance. In quasi-2D other effects in the scattering become important, one example is a confinement induced resonance (CIR). Recently Haller *et al.* [1] observed of a CIR in a 1D Bose gas. A pole in the scattering amplitude occurs when the transverse oscillator length $a_\perp = \sqrt{\hbar/m\omega_\perp}$ (where m is the mass and $\omega_\perp$ is the axial trapping frequency) becomes equal to the 3D s-wave scattering length a_{3D}, and colliding atoms can resonantly form molecules in the first excited state.

To form a 2D Fermi gas we must satisfy $k_BT, E_F < \hbar\omega_\perp$. In our experiments, a 2D optical trap is formed by a light sheet produced by tightly focusing a circular Gaussian beam in one direction with a cylindrical lens. The trapping frequencies are $\omega_\perp/2\pi \approx$ 4 kHz and $\omega_r/2\pi \approx$ 70 Hz in the tightly and weakly confined directions respectively, giving an aspect ratio of $\sim$60. For an ideal Fermi gas, $E_F < \hbar\omega_\perp$ for $N \lesssim$ 2000 is necessary to achieve the 2D regime.

We have observed reduced dimensionality by measuring the transverse cloud width across the Feshbach resonance after a short time of flight. The width shows a peak at 816 G (Fig. 1a) for an atom number of $\sim$4000. The inset shows the width of a 3D cloud vs. magnetic field which displays the usual monotonic increase from the BEC to BCS limits. We interpret the increase in the 2D case as arising from the production of molecules in excited transverse modes which expand more quickly upon release, as expected for a confinement induced resonance. At large N (Fig. 1b) the width in the 2D case shows a broader peak at a higher field but is still vastly different from the 3D case (inset). This we believe to be due to higher transverse excited states being populated through collisions but we are yet to quantitatively model these experiments. Our goal is to understand how CIRs affect pairing and superfluidity in lower dimensional Fermi gases.



(a)



(b)

Fig. 1: Observed width of a quasi-2D Fermi gas after expansion for (a) $N = 4000$ atoms and (b) $N = 10^5$ atoms. Insets show the corresponding widths after expansion from our regular 3D optical trap. Solid lines are a guide to the eye.

References

[1] E. Haller, M. Gustavsson, M. J. Mark, J. G. Danzl, R. Hart, G. Pupillo, and H-C, Nagerl, Science **325**, 1224 (2009).