p-wave Feshbach resonances in ^{6}Li

J. Fuchs, P. Dyke, G. Veeravalli, E. Kuhnle, C. Ticknor, W. Rowlands, P. Hannaford and C. J. Vale
ACQAO, Swinburne University of Technology, Australia

The ability to control atom-atom interactions in ultracold gases is possible through magnetically tunable Feshbach resonances. These occur when the energy of two colliding atoms coincides with a bound molecular state for a different combination of internal atomic states. The scattering length diverges at the resonance, being large and positive (repulsive) below resonance where a bound molecular state exists, and large and negative (attractive) above the resonance. To date most experiments, including ours, have utilised s-wave scattering resonances for the production of molecular Bose-Einstein condensates and fermionic superfluids [1].

Feshbach resonances involving scattering with nonzero angular momentum also exist. Higher order scattering is characterised by a centrifugal barrier which usually suppresses collisions at low energy. At resonance, however, this can be overcome and strong interactions and pairing can occur. Recently, the first p-wave ($l = 1$) Feshbach molecules were produced and detected in an ultracold gas of ^{40}K [2]. Condensates of such molecules hold the promise of probing superfluidity based on pairing with higher order partial waves. A limitation for ^{40}K p-wave molecules is that dipolar relaxation limits their lifetime to a few milliseconds. In ^{6}Li there are three p-wave Feshbach resonances corresponding to the different combinations of $|F = 1/2, m_F = +1/2\rangle$ ($|1\rangle$) and $|1/2, -1/2\rangle$ ($|2\rangle$) states. One of these resonances involves two atoms in the lowest energy spin state, $|1\rangle$, and is thus not susceptible to dipolar relaxation. Hence molecules formed on this resonance have the potential to be much longer lived.

We have recently measured the binding energies of ^{6}Li p-wave molecules using radio frequency (rf) magneto-association spectroscopy for all three resonances. The binding energy increases linearly with magnetic field detuning and our measured values of $113 \pm 7\,\mu$K/G, $111 \pm 6\,\mu$K/G and $118 \pm 8\,\mu$K/G for the $|1\rangle$-$|1\rangle$, $|1\rangle$-$|2\rangle$ and $|2\rangle$-$|2\rangle$ resonances, respectively, are in good agreement with theoretical predictions. Figure 1 below shows a typical magneto-association spectrum and the measured binding energies for the $|1\rangle$-$|1\rangle$ resonance with a linear fit. We can also infer near-resonant properties of the scattering states from the measured conversion rates as a function of detuning [3].

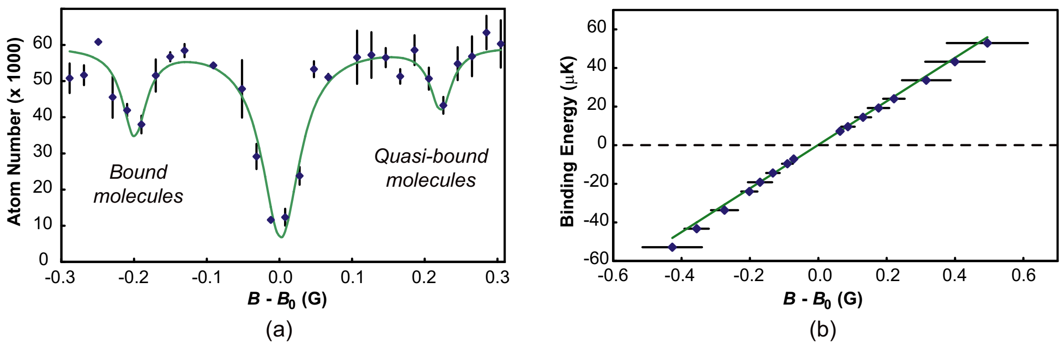

Figure 1: (a) Magneto-association spectrum showing atom loss for bound and quasibound ^{6}Li molecules (ν_{rf} = 300 kHz). (b) Binding energy of ^{6}Li p-wave molecules vs. magnetic field detuning (B_0 = 159 G).

References

[1] S. Jochim *et al.*, Science **302**, 2102 (2003); M. Greiner *et al.*, Nature **426**, 537 (2003); M. Zwierlein *et al.*, Phys. Rev. Lett. **91**, 250401 (2003); T. Bourdel *et al.*, Phys. Rev. Lett. **93**, 050401 (2003); J. Fuchs *et al.*, J. Phys. B **40**, 4109 (2007).
[2] J.P. Gaebler *et al.*, Phys. Rev. Lett. **98**, 200403 (2007).
[3] J. Fuchs *et al.*, arXiv:0802.3262.