\textbf{$p$-wave Feshbach resonances in $^6$Li}

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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 $|F = 1/2, m_F = \pm 1/2 \rangle (|1\rangle)$ 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].

\begin{figure}[h]
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\includegraphics[width=\textwidth]{fig1.png}
\caption{(a) Magneto-association spectrum showing atom loss for bound and quasibound $^6$Li molecules ($\nu_{rf} = 300$ kHz). (b) Binding energy of $^6$Li $p$-wave molecules vs. magnetic field detuning ($B_0 = 159$ G).}
\end{figure}

References