Molecular Probe of the BCS/BEC Crossover in ^{6}Li

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Recent experiments have explored superfluidity and Cooper pairing in atomic Fermi gases of ^{40}K and ^{6}Li. These experiments employ a Feshbach resonance to create a strongly interacting gas. A Feshbach resonance involves a collision of a pair of atoms in an open channel coupled to a bound molecular state of a closed channel. An exact theory requires a two-channel model in which the weakly-bound molecules are hybridized combinations of open-channel atoms with "bare" molecules in the closed channel. However, traditional condensed matter models of the BCS/BEC crossover are single channel models for which there is no closed channel. The applicability of these models to current atomic physics experiments is a point of debate, and bears on the relevance of these experiments to high-temperature superconductors. Furthermore, the details of the hybridization have significant implications for the nature of Fermi superfluidity near a Feshbach resonance as it determines the nature of the pairs; that is, whether they are small and molecular in character, or large extended objects akin to Cooper pairs.

We create a Bose-Einstein condensate of molecular ^{6}Li on the side of the broad resonance and use this condensate as a starting point to explore the crossover. We measure the closed-channel molecular content of the many-body state using optical spectroscopy to project out the singlet component of the pairs. Contrary to two-body physics, we find weakly-bound molecules on the so-called "BCS" side of the resonance. While two-body physics predicts that the closed-channel component goes to zero at resonance, we find instead a monotonically decreasing closed-channel component on *both* sides of the resonance. Thus, the many-body physics is continuous across the resonance, and the distinction between the low-field and high-field sides is artificial. The closed-channel fraction, however, is extremely small and on average, there are no closed-channel molecules in the gas on resonance. The molecular probe also provides a quantitative measurement of the local pair correlations. Pair correlations are measured from the weakly interacting BEC regime, and for the first time, into the BCS regime where $k_F|a| < 1$. The measurements agree with a single-channel theory in the respective limits.