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Phase-Separation in a Polarized Fermi Gas[1]

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In fermionic systems, the formation of pairs between two constitute components is the essential ingredient of superfluidity and superconductivity. While many advances have been made in understanding pairing between components with equal chemical potentials, the possible pairing mechanisms and corresponding phases in systems with mismatched chemical potentials are topics of active debate. In contrast to the difficulties in generating magnetized superconductors, mismatched Fermi surfaces can be readily realized by creating an imbalance between the populations of two spin components in a gas of ultracold fermionic atoms. Exotic new states of matter are predicted for the unbalanced systems that, if realized, may have important implications for our understanding of nuclei, compact stars, and quantum chromodynamics. We investigate a strongly interacting Fermi gas of ^{6}Li atoms with unbalanced populations by *in-situ* imaging of real-space density distributions [3], [4]. We observe two low-temperature regimes, both with an evenly paired core. At the lowest temperatures, an unpolarized core separates from the excess unpaired atoms by a sharp boundary, which is consistent with a phase separation driven by a first-order phase transition. Moreover, the unpolarized core deforms with increasing polarization, presumably due to surface tension at the superfluid/normal boundary. At higher but still degenerate temperatures, an unpolarized central core remains up to a critical polarization, but does not deform. In this case, the boundaries are not sharp, indicating a partially-polarized shell between the core and the unpaired atoms, consistent with a second-order phase boundary. The observed temperature dependence supports a phase diagram with a tricritical point. The phase- separated phase is only possible for temperatures below the tricritical point, while the higher temperature phase is a polarized superfluid.

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[3]G.B. Partridge *et al.*, *Science* **311**, 503 (2006).
[4]G.B. Partridge *et al.*, *Phys. Rev. Lett.* **97**, 190407 (2006).