Unitary thermodynamics calculated from thermodynamic geometry

GEORGE RUPPEINER, New College of Florida — Degenerate atomic Fermi gases of atoms near a Feshbach resonance show universal thermodynamic properties, which are here calculated with the geometry of thermodynamics, and the thermodynamic curvature \( R \). Unitary thermodynamics is expressed as the solution to a pair of ordinary differential equations, a "superfluid" one valid for small entropy per particle \( z \equiv S/Nk_B \), and a "normal" one valid for large \( z \). These two solutions are joined at a second-order phase transition at \( z = z_c \). Define the internal energy per particle in units of the Fermi energy as \( Y = Y(z) \). For small \( z \), \( Y(z) = y_0 + y_1 z^\alpha + y_2 z^{2\alpha} + \cdots \), where \( \alpha \) is a constant exponent, \( y_0 \) and \( y_1 \) are scaling factors, and the series coefficients \( y_i \) \((i \geq 2)\) are determined uniquely in terms of \((\alpha, y_0, y_1)\). For large \( z \) the solution follows uniquely if, in addition, we specify \( z_c \), with \( Y(z) \) diverging as \( z^{5/3} \). The four undetermined parameters \((\alpha, y_0, y_1, z_c)\) were determined by fitting the theory to experimental data taken by a Duke University group on \(^6\text{Li}\) in an optical trap with a Gaussian potential. The best fit of this theory to the data has \( \chi^2 \sim 1 \).