Magic gap ratio at the "BCS Superconducting to Bose-Einstein Condensate" crossover in the high-T_c cuprates

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Superfluidity of fermions occurs when they form pairs. In the weak pairing limit, this behavior is well captured by the Bardeen-Schrieffer-Cooper (BCS) theory of superconductivity. In the strong pairing limit, pairs can form at temperatures much higher than that of the superfluidity causing the superfluidity to occur by a process known as Bose-Einstein condensation (BEC), analogous to that occurring in liquid ^{4}He. A BCS-BEC crossover has been observed in a cold atomic Fermi gas, where it is possible to continuously tune the strength of the pairing interactions. Whether such a crossover occurs in other systems such as the high-T_c cuprates has remained an open question.

MagLab scientists discovered a BCS-BEC crossover in the high-T_c cuprates by identifying a universal magic gap ratio $2\Delta/k_BT_c \approx 6.5$ (where Δ is the pairing gap and T_c is the superconducting transition temperature) at which the paired-fermion condensates become optimally robust. At this gap ratio, corresponding to the unitary point in a cold atomic Fermi gas, the jump in the specific heat at T_c reaches a maximum for seven different cuprates. In the cuprates, this jump is peaked at the magic gap ratio when Δ corresponds to the antinodal spectroscopic gap, thus reinforcing its interpretation as the superconducting pairing gap in the cuprates. The peak also coincides with a normal state specific heat maximum, which is indicative of a pseudogap above the superconducting transition temperature arising from pairing fluctuations.

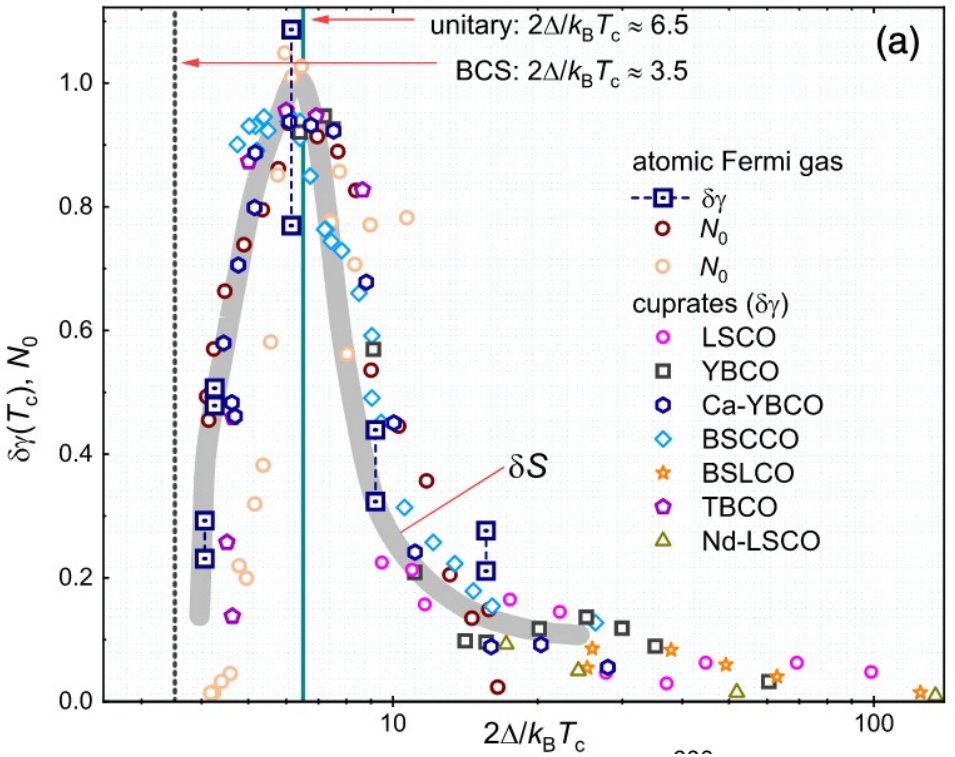

Figure: A comparison of the jump $\delta\gamma$ at T_c in the specific heat coefficient for seven different cuprate superconductors, with the equivalent quantity in a cold atomic gas. Also shown are the change in entropy δS and the condensate fraction N_0. All quantities are plotted versus the gap ratio, $2\Delta/k_BT_c$. The common peak at $2\Delta/k_BT_c \approx 6.5$ indicates a "magic gap ratio" at a crossover from BCS to BEC condensation.

Facility used: MagLab's Pulsed Field Facility

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