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**Lee-Yang cluster expansion approach to BCS-BEC crossover**

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A dilute gas of spin-1/2 Fermi atoms can continuously evolve from Cooper pairing to Bose-Einstein condensation (BEC) of tightly-bound dimers by changing the strength of interaction between them. This is called BCS-BEC crossover and has realized by using a ultracold atomic gases. In this work, we propose a new systematic approach to describe the BCS-BEC crossover based on a cluster expansion method of Lee and Yang. Here, the cluster expansion is a systematic expansion of the equation of state in terms of the fugacity $z := e^{\beta\mu}$ as $\beta\lambda^3 p = 2z + b_2 z^2 + b_3 z^3 + \ldots$, with inverse temperature $\beta = (k_B T)^{-1}$, chemical potential $\mu$, pressure $p$, and thermal de Broglie length $\lambda := (2\pi\hbar\beta/m)^{1/2}$. We show the following results: (i) in the weak-coupling limit, the Thouless criterion and the number equation of Nozieres and Schmitt-Rink are derived, and thereby the critical temperature is identical with that of the BCS theory; (ii) in the strong-coupling limit, the critical temperature is identical with that of the BEC of non-interacting dimers; (iii) The exact second cluster integral $b_2$, which is dominant in the high-temperature region, is also included in the expansion for any value of an s-wave scattering length $a$.

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