Hugenholtz-Pines Theorem for Multicomponent Bose-Einstein Condensates

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The Hugenholtz-Pines relation is an important relation for understanding the low-energy properties of BECs, which is strongly related to the broken symmetry. For a scalar BEC, this relation provides the gapless condition for the single-particle excitation. For the spinor BEC, the SO(3) symmetry can be explicitly broken by an external magnetic field.

In this talk, I will talk about the Hugenholtz-Pines relation for Bose-Einstein condensates with internal degrees of freedom. I will discuss a low-energy Ward-Takahashi identity for the system with the linear and quadratic symmetry breaking terms. This identity serves to organize the Hugenholtz-Pines theorem for multicomponent BECs, such as the spin-f spinor BEC in the presence of a magnetic field. The experimental method based on the Stern-Gerlach experiment will also be discussed.