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Mechanism of Spontaneous Rotation in One-dimensional Cold Atoms

Masahiro Sato (Condensed Matter Theory Laboratory, RIKEN)

Cold-atom systems have been studied intensively for the last decade. In this exciting field, we focus on harmonically-trapped one- dimensional (1D) Bose gases. 1D atom systems have been constructed experimentally by applying a 2D trap potential to 3D cold atoms. From the theoretical viewpoint, the 1D systems are expected to be fabricated as follows: the trap potential makes the spectrum of the 2D trap-plane dynamics discrete, and then almost all the atoms enter in the lowest band. So far, many theoretical works of 1D cold atoms have been done under this assumption. However, if we change the total number of cold atoms, the strength of the potential, etc, we can obtain a situation where atoms occupy the higher bands as well as the lowest one. Following this idea, we consider effects of higher bands in 1D repulsively interacting Bose gases. If we assume that the trap potential is a 2D harmonic type, the angular momentum "L" defined in the 2D plane becomes a good quantum number and the band structure in the remaining 1D direction is followings: the lowest band has L=0, the second lowest ones are doubly degenerate with L=+1 and -1, etc. For simplicity, we suppose that Bose atoms occupy only the lowest three bands. For this situation, we show that when the inter-atom interactions are sufficiently weaker than the trap potential, they and quantum fluctuations make the occupation numbers of L=+1 and -1 bands imbalanced, and as a result, a spontaneously rotating ground state emerges. In this state, the Z_2 reflection symmetry is spontaneously broken. I will talk about the mechanism of this new symmetry breaking in detail.