Fragmentation of a Trapped Bosonic Mixture

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Fragmentation of Bose-Einstein condensates implies the macroscopic occupation [1-6] of more than one natural orbital of the reduced one-particle density matrix [7]. Fragmentation in bosonic mixtures can obviously be richer but is generally less studied. In the present talk, we use a solvable model, the harmonic-interaction model for mixtures [8-10], to explore the fragmentation of bosonic mixtures analytically. Obtaining closed-form expressions for the eigenvalues of the reduced one-particle density matrices, we investigate the properties of a fragmented condensate embedded in a bosonic bath. As a limiting case, the fragmentation of non-interacting bosons interacting with a single impurity is analyzed.

What about the fragmentation of pairs? Pairs' fragmentation means the macroscopic occupation of more than one natural geminal of the reduced two-particle density matrix. In a mixture, there are two kinds of pairs, pairs of identical bosons and pairs made of distinguishable bosons. Using the symmetric harmonic-interaction model for mixtures and getting closed-form expressions for the eigenvalues of the intra-species and inter-species reduced two-particle density matrices, properties of pairs' fragmentation in the mixture are investigated [11]. The role of the center-of-mass and relative center-of-mass degrees-of-freedom is identified. As an additional result, the exact Schmidt decomposition of the mixture is derived [11,12]. The entanglement between the two species is governed by the coupling of their intra-species center-of-mass degrees-of-freedom, and it persists at the infinite-particle-number limit when fragmentation vanishes and turns 100% condensation.

References

[1] M Girardeau, Phys. of Fluids **5**, 1468 (1962)

[2] P Noziéres and D Saint James, J. Phys. (Paris) **43**, 1133 (1982)

[3] R W Spekkens and J E Sipe, Phys. Rev. A **59**, 3868 (1999)

[4] A I Streltsov, L S Cederbaum and N Moiseyev, Phys. Rev. A **70**, 053607 (2004)

[5] E J Mueller, T-L Ho, M Ueda and G Baym, Phys. Rev. A **74**, 033612 (2006)

[6] U R Fischer, A U J Lode and B Chatterjee, Phys. Rev. A **91**, 063621 (2015)

[7] A J Coleman and V I Yukalov, Reduced Density Matrices: Coulson's Challenge, Lectures Notes in Chemistry **72**, Springer, Berlin, 2000

[8] M S Osadchii and V V Muraktanov, Int. J. Quantum Chem. **39**, 173 (1991)

[9] P A Bouvrie, A P Majtey, M C Tichy, J S Dehesa and A R Plastino, Eur. Phys. J. D **68**, 346 (2014)

[10] O E Alon, J. Phys. A **50**, 295002 (2017)

[11] O E Alon, Atoms **9**, 92 (2021)

[12] O E Alon and L S Cederbaum, J. Phys. Conf. Ser. **2249**, 012011 (2022)