Single-particle momentum distributions for bosonic trimer states in two and three dimensions

M. T. Yamashita[(a)], F. F. Bellotti[(b,c,d)], T. Frederico[(b)],
D. V. Fedorov[(c)], A. S. Jensen[(c)], N. T. Zinner[(c)]

[(a)] Instituto de Física Teórica, UNESP, São Paulo, Brazil
[(b)] Instituto Tecnológico de Aeronáutica, São José dos Campos, Brazil
[(c)] Department of Physics and Astronomy, Aarhus University, Aarhus, Denmark
[(d)] Instituto de Fomento e Coordenação Industrial, São José dos Campos, Brazil

Cold atomic gases are a rich playground to study not only few-body correlations but also the effects of dimensionality by changing the applied optical fields. A notorious dimensional effect occurs in the spectrum of three-boson systems in the universal limit when we pass from three (3D) to two (2D) dimensions. In this case, for a two-body energy (E_2) equal zero, the infinite number of three-body bound states, which appears as a consequence of the Efimov effect [1], is reduced to zero because in 2D there is only one scale given by E_2, such that the three-body bound states (there are only two in 2D) are proportional to this two-body energy. Another interesting quantity that is sensitive to dimensional effects is the single-particle momentum distributions, $n(\mathbf{k})$.

The asymptotic behavior of the leading-order term of the single-particle momentum distribution, $n(\mathbf{k}) = \lim_{k\to\infty} C_2/k^4$, gives the Tan's contact parameter, C_2 [2], which connects few- and many-body worlds. The tail of the leading-order term is the same for one, two or three dimensions since it results only from the two-body physics. However, the next-to-leading-order term, which gives the three-body contact parameter (C_3), changes drastically. For three bosons in 3D it presents a log-periodic behavior [3,4], coming from the Efimov physics, whereas in 2D it has only a logarithm dependence on momentum [5].

In this presentation, we will show the single-particle momentum distributions for three bosons interacting by a zero-range potential in 2D and 3D. Several formulas derived analytically are compared with numerical results. In 2D [5], we explicitly show that the two-body contact parameter is universal and then demonstrate that the momentum distribution at next-to-leading order has a logarithmic dependence on momentum which is vastly different from the three-dimensional case. Based on this, we propose a scheme for measuring the effective dimensionality of a quantum many-body system by exploiting the functional form of the momentum distribution.

In 3D [4], we solve the three-body bound state problem for mass imbalanced systems of two identical bosons and a third particle in the universal limit. The system displays the Efimov effect and we use the momentum-space wave equation to derive formulas for the scaling factor of the Efimov spectrum for any mass ratio. We consider the single-particle momentum distribution analytically and numerically and analyse the tail of the momentum distribution to obtain the three-body contact parameter. Our finding demonstrate that the functional form of the three-body contact term depends on the mass ratio and we obtain an analytic expression for this behavior. To exemplify our results, we consider mixtures of Lithium with either two Caesium or Rubium atoms which are systems of current experimental interest.

[1] V. Efimov, Yad. Fiz **12**, 1080 (1970); Sov. J. Nucl. Phys. **12**, 589 (1971).

[2] S. Tan, Ann. Phys. **323**, 2952 (2008); *ibid* **323**, 2971 (2008); **323**, 2987 (2008).

[3] Y. Castin and F. Werner, Phys. Rev. A **83**, 063614 (2011)

[4] M. T. Yamashita *et al.*, arxiv:1303.5883 (2013).

[5] F. Bellotti *et al.*, Phys. Rev A **87**, 013610 (2013).

E-mail: yamashita@ift.unesp.br