Three-body recombination at the scattering length's zero-crossings

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We investigate the tree-body recombination rates in a gas of ultracold ^{7}Li atoms in the vicinity of scattering length's zero-crossings, e.g. when $a \to 0$. We show that although the two-body scattering length a and, thus, the two-body collisional cross-section vanish, the three-body recombination rates stay finite. Moreover, they can still be related to the relevant two-body parameters, a and R_e, where R_e is the effective range of the interaction potential.

Recently it has been shown that the two-body physics plays a decisive role in the universal few-body physics in ultracold gases, e. g. in the limit of $a \to \infty$ [1 − 3]. Here we study the questions of how far the importance of two-body physics extends and what parameters govern the three-body processes in the opposite, non-universal limit, e.g. when the scattering length vanishes? These questions, to some extent, were addressed in recent theoretical studies in Refs. [4 − 6].

Assuming the dominance of the two-body physics in three-body processes, we start by considering the effective range expansion of the scattering phase shift $\delta(k)$ in its usual form: $k\cot(\delta(k)) = -1/a + R_e k^2/2$. However, when $a \to 0$ the first term diverges and to compensate this divergence the second term diverges as well ($|R_e| \to \infty$), which makes the above expression inconvenient in this limit. A better form of the effective range expansion can be obtained from the standard expression with a simple algebra: $-\tan(\delta(k))/k = a + R_e a^2 k^2/2$. We show that although neither a nor R_e are good lengths at zero-crossings, their combination in the form of the effective recombination length $L_e = (-R_e a^2/2)^{1/3}$ captures remarkably well the behaviour of the three-body recombination rates. No farther knowledge of the short-range two-body or three-body potentials are needed for this purpose. Moreover, while two-body collisional cross-section becomes energy dependent at zero-crossings, the tree-body recombination rate coefficient remains energy independent. In addition we show that L_e continues to be the dominate length in the inelastic three-body processes for larger scattering lengths up to a region where the universal three-body physics takes over and the leading length becomes a.

Having connected these new measurements with the previously reported results in the universal limit ($a \to \infty$) [7] we can now predict the entire magnetic field dependence of the three-body recombination rates. We thus can point out a non-trivial magnetic field value at which they should vanish notifying a region where Bose-Einstein condensate's lifetime should be optimal.

References

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