Going beyond one-body coherence in atomic gases: how to observe pair/counter-flow superfluidity in one-dimensional bosonic mixtures

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We investigate the breakdown of one-body coherence (conventional condensation or quasi-condensation) in asymmetric binary mixtures of hardcore bosons in one-dimensional optical lattices, due to the competition of conventional superfluidity with cooperative superfluidity, namely pair superfluidity (PSF) and counter-flow superfluidity (CSF). Using numerically exact methods, we find a very strong asymmetry between PSF and CSF: while PSF is found to occur for balanced populations at any filling and for a large range of mass ratios, CSF is only observed at half filling, in contrast with predictions from bosonisation. Moreover both phases are found to be very fragile to population imbalance between the two species: a difference of only one particle can already restore the one-body coherence. Yet, in the case of PSF, parabolic traps (which are inevitable in experiments) come to the rescue, allowing to rebalance the populations in the trap center, and leading to the suppression of the global one- body coherence in the trapped system.

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