Atom-atom correlations in colliding Bose-Einstein condensates

M. Ögren[1], C. M. Savage[2], A. Perrin[3], D. Boiron[3], V. Krachmalnicoff[3], C. I. Westbrook[3], P. Deuar[4], and K. V. Kheruntsyan[1]

[1] *ACQAO, School of Mathematics and Physics, University of Queensland, Brisbane, QLD 4072, Australia*

[2] *ACQAO, Department of Physics, Australian National University, Canberra, ACT 0200, Australia*

[3] *Institut d'Optique, CNRS, Universite Paris-Sud, 91127 Palaiseau, France*

[4] *LPTMS, Université Paris-Sud, CNRS, 91405 Orsay, France*

Experiments with colliding Bose-Einstein condensates (BECs) [1, 2] are currently attracting considerable attention in the field of ultra-cold quantum gases. A recent breakthrough in this area is a direct detection [2] of atom-atom pair correlations in the *s*-wave scattering halo formed in the collision of metastable helium ($^4He^*$) condensates. Such experimental advances pose increasingly demanding challenges to theory due to the need to provide quantitatively accurate descriptions of the experimental results in realistic parameter regimes.

In collaboration with ACQAO partners at the Institute d'Optique, we have performed first-principles simulations of the quantum dynamics of $^4He^*$ BEC collisions and analysed the pair correlations of the scattered atoms [3]. The results are generally in good agreement with the experiment, however, the relatively short simulation durations using the positive-*P* representation method mean that the long time dynamics of the collision dynamics is not yet fully understood. We are currently developing alternative theoretical approaches that can model this behavior.

Additionally, we have developed approximate analytic approaches to the short-time dynamics of atom-atom correlations [4], which give a simple, analytically transparent understanding of the width of the correlation functions. Finally, we are have started to investigate the BEC collision dynamics in a new geometry, in which the collision is taking place in the direction perpendicular to the longitudinal axis of the colliding BECs. This is different to the original experimental configuration of Ref. [2] and gives better detection access to atoms on the *s*-wave scattering halo. The new geometry is also sensitive to detecting Bose enhancement in the direction along the long axis of the condensates. The figure below shows three orthogonal slices of the atomic density distribution in 3D obtained from first principle simulations using the positive-*P* representation method; the directional Bose enhancement can be seen as higher density regions on the scattering shell.

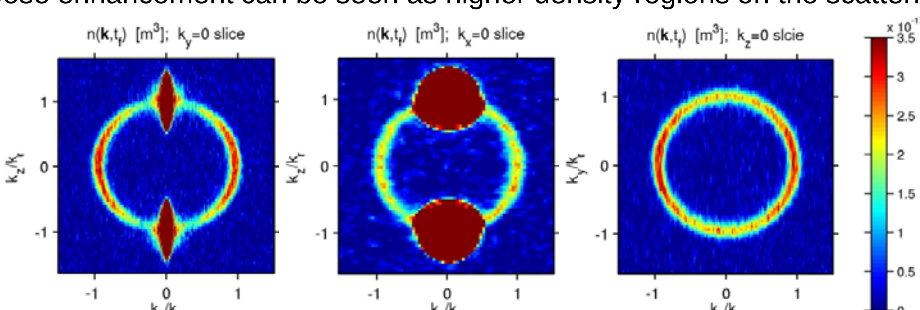

Fig. 1. Three orthogonal slices of the atomic density distribution in momentum space, showing the spherical shell of *s*-wave scattered atoms. The darker regions in the first and second panels (which are off the scale) correspond to the momentum distributions of the two colliding condensates.

References

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