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Bose–Einstein condensates: recent advances in collective effects/Avencées récentes sur les effets collectifs dans les condensats de Bose–Einstein

Foreword

Since the first observation of a Bose Einstein Condensate (BEC) with neutral atoms in 1995, the field of trapping and cooling atoms has developed dramatically. The pioneering works on the realisation of BEC, consisting of a sudden macroscopic occupation of a single quantum state, have been awarded the Nobel prize of 2001.

The making of a Bose Einstein Condensate with ultracold gases has stirred the interest of theoreticians for these new degenerate systems. Compared to the more traditional situations where quantum many body effects are relevant, such as superfluids and superconductors, this has the huge advantage of introducing a small dimensionless parameter in the dilute limit, the density times the cube of the scattering length, that can be used in various expansion schemes. The various predictions made are therefore compared to experimental results without any adjustable parameters.

This special issue presents the views of several physicists and mathematicians on various questions related to BEC. The earliest successful attempt of building a theory for the weakly interacting case is due to Bogoliubov [1]. He has established a reduced quadratic Hamiltonian for a dilute Bose gas close to $T = 0$ which allows for the interpretation of low energy excitations in terms of quasiparticles. The condensate itself is currently described by the Gross–Pitaevskii (G–P) equation, valid in the dilute limit. This theoretical framework permits the investigation of various phenomena, such as the wake behind an obstacle (C.-T. Pham et al.), the effects of rotation, including the generation of vortices with an interesting structure when the effects of the trapping potential and of the rotation are both included (A. Aftalion).

Finite temperature effects play a role too in real BEC. They are present both at equilibrium, change of transition temperature due to interactions (M. Holzman et al.), without and with differential velocity between the normal gas and the condensate (Y. Pomeau, S. Rica).

This brings in the difficult and largely yet unsolved question of a coherent picture of the interacting condensate and normal gas. The kinetic theory without condensate is already a tricky business (D. Guéry-Odelin and Lahaye). The condensate seemingly grows up out of a finite time singularity of solutions of the Boltzmann–Nordheim kinetic theory, but in a yet not fully understood manner (L. Saint-Raymond). Even the splitting into reversible mean field dynamics (G–P) and irreversible ‘collisions’ is not so clear-cut, because the mean field itself may display irreversible behavior, although it satisfies formally a property of time reversal symmetry. This is linked, of course, to the complexity of the notion of time reversal symmetry for systems with infinitely many degrees of freedom, such as the nonlinear G–P equation (C. Josserand, C. Connaughton and Y. Pomeau).

Several prospective applications are under study, while others are already within reach. Among them are: atomic waves guiding, ‘integrated’ atom optics, an ‘atom LASER’, Quantum Information Processing, and many others. The prominent common feature of all these challenging tasks is their strong link to the field of degenerate quantum gases at low dimensions (I. Carusotto and Y. Castin, V. Zagrebnov et al.).

As shown by this brief summary, the various contributions in this special issue highlight fundamental questions raised by the creation of Bose–Einstein condensate as well as some of their possible applications. We hope that, as ourselves, the reader will find them stimulating and will be led to contribute to some of these issues.

Reference

[1] N.N. Bogoliubov, J. Phys. 11 (1947) 23.

Yves Pomeau
Laboratoire de physique statistique
l’École normale supérieure
24, rue Lhomond
75231 Paris cedex 05
France
E-mail address: yves.pomeau@lps.ens.fr (Y. Pomeau)

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David Guéry-Odelin
Laboratoire Kastler Brossel
l'École normale supérieure
24, rue Lhomond
75231 Paris cedex 05
France
E-mail address: dgo@lkb.ens.fr (D. Guéry-Odelin)

Vincent Hakim
Laboratoire de physique statistique
l'École normale supérieure
24, rue Lhomond
75231 Paris cedex 05
France
E-mail address: hakim@lps.ens.fr (V. Hakim)