Report on the thesis "Positive ions, collective modes, and Anderson localisation in ultracold gases" by Pietro Massignan

This work is an accomplished thesis showing mastery of the subject of cold atom physics and containing original work on three different problems.

The thesis begins with a brief but comprehensive introduction to the subject. It outlines the major topics to be addressed and provides an overview of the state of the entire field of cold atom physics. Chapter 2 gives a nice review of the use of effective potentials to describe scattering from a deep potential when the atoms are cold, including finite range and finite energy corrections.

Chapter 3 contains the first of the new pieces of work. Here, the problem addressed is that of a charged ion embedded in an otherwise uniform condensate. The first conclusion is an interesting one that, in a typical dilute case, about 10-100 atoms from the condensate are trapped by an alkali atom. For higher densities where the Gross-Pitaevski equation is valid, interesting and novel features are revealed whereby multiple solutions can occur, appearing and disappearing in pairs. This may be observable physics. We note the good use of asymptotic analysis in this section.

Chapter 4 addresses the very different and highly topical problem of the collective modes in a two component fermi gas. The particular point addressed here is the crossover from hydrodynamic to collisionless regimes of collective oscillation. The methodology used is the linearised quantum Boltzmann equation, and the validity of this approximation is well justified. The results show that the hydrodynamic regime is difficult to reach in experiment and thus cast some doubt on the previous experimental interpretation (by others).

A very different and original problem emerges in chapter 5 where cold atomic gases are used to simulate disorder localisation physics. While this is an old problem, it is never studied in condensed matter systems in its original "non-interacting" form, and experiments in the weakly interacting and coherent limit do not exist. Some earlier work has been done in cold atom systems by providing a weak random potential using laser speckle, but this presents a length scale too large to permit good macroscopic averaging. The proposal here is to use a second species of atom trapped at random sites in an optical lattice. The analysis is thorough and believable, and it is supported both by detailed numerical simulations of wave functions and by a solid analysis of the elastic and inelastic scattering terms. This seems to be an attractive idea which is likely to provide excellent stimulation for new experiments.

The thesis defence was entirely satisfactory. The material was presented in a clear and understandable fashion; answers to the questions posed were thoughtful and comprehensive.

Overall this is an excellent thesis containing several pieces of independent and original work, lucidly explained. We are particularly impressed by the breadth of the thesis: The three topics discussed have little overlap, and each requires a completely different background that the author had to acquire. The thesis is very well written and demonstrates the author's mastery of the theory presented. We recommend the acceptance of this thesis for the PhD degree.

P. Littlewood   H. T. C. Stoof   A. D. Jackson   February 3, 2006