

Report on the programme “Quantum Gases” at IHP

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This trimester (workshop) was organized by Yvan Castin (LKB-ENS, Paris), Tin-Lun Ho (Ohio State University, USA), Antony Leggett (University of Illinois at Urbana Champaign, USA), and Gora Shlyapnikov (LPTMS, Orsay). The key idea was to bring together physicists from various fields, actively working at present on Quantum Gases, in order to discuss latest findings and prospects, stimulate ongoing and future collaborations, and give educational courses for students of the Paris and Ile de France area. After the discovery of Bose-Einstein condensation (BEC) in ultracold clouds of alkali atoms in 1995, the field of quantum gases underwent a tremendous boost and is now highly interdisciplinary. It attracts researchers from atomic/optical physics, condensed matter physics, nuclear and high-energy physics, non-linear and mathematical physics. This is due to a wide spectrum of scientific activity and remarkable achievements in the last 12 years, which include:

- production of both bosonic and fermionic gases, or their mixtures, and opening wide avenues for atom optics with cold atoms and future applications, such as atom lasers or BEC interferometry;
- trapping of atoms in macroscopic harmonic potentials, mimicking a bulk phase, or in optical lattices, mimicking the tight binding regime of condensed matter physics and drawing prospects for quantum information with cold atoms;
- creation of atomic systems in quasi-periodic or disordered potentials, and opening the way to the physics of Anderson localization;

- adjusting the dimensionality of the system at will, so that the gases may be one-dimensional or two-dimensional, allowing the observation of the Lieb-Liniger gas in 1D and renewing the interest to integrable models, and leading to the investigation of the Berezinskii-Kosterlitz-Thouless transition in 2D;
- tuning the interaction between atoms by a Feshbach resonance and creating strongly interacting Fermi gases, which brings in analogies with neutron matter and superconductivity, in the latter case regarding the BCS-BEC crossover from a weakly interacting Fermi gas to the strongly interacting regime (unitary gas) and then to the regime of Bose-Einstein condensation of weakly bound molecules of fermionic atoms;
- creation and melting of vortex lattices in rapidly rotating Bose gases, which draws prospects towards achieving strongly correlated Quantum Hall states;
- production of spinor Bose-Einstein condensates representing a gaseous analog of condensed matter magnetic systems, and creation of dipolar quantum gases which are expected to exhibit peculiar regimes of quantum degeneracy.

In most cases, there was a coherent interaction between experiment and theory, and theoretical studies were providing a proper guidance for experiments. This predetermined an active participation of experimental physicists in the trimester.

As a consequence of such a wide activity, the spectrum of theoretical problems to be investigated in the context of quantum gases is very broad, and covers several subfields of physics, including condensed matter physics, mathematical physics, atomic and molecular physics, quantum optics, nuclear physics, statistical and computational physics, non-linear physics. The emphasis in the trimester was put on several subjects, some of which can be identified as hot topics of the physics of quantum gases:

- Fundamentals of atomic and condensed matter physics, and atom optics with Bose-Einstein condensates;
- Mathematical aspects of the physics of quantum gases;
- Low-dimensional atomic systems;

- Strongly interacting Fermi gases and few-body physics;
- Correlated atomic systems in optical lattices;
- Quantum gases in disorder;
- Rapidly rotating quantum gases;
- Spinor and dipolar quantum gases.

In order to cover this broad spectrum, we found it necessary to structure the trimester in several layers, going from general aspects to specific ones:

- a series of lectures (three per week, duration 1.5 hour each), presenting the main concepts and results of each subfield; the lecturers were well established senior scientists, four of them being Nobel prize winners (Claude Cohen-Tannoudji, Antony Leggett, William Phillips, Wolfgang Ketterle).
- a series of seminars (two per week, duration 1 hour each), presenting recent results in a detailed and pedagogical way accessible not only to the narrow experts.
- a series of informal talks given by volunteers among the participants (four per week, duration 0.5 hour each), presenting the latest results in a more concise way. This series was organized by T.-L. Ho and M. Lewenstein (Barcelona).
- informal discussions of the participants with experimental group leaders, to ensure transfer of knowledge between theory and experiment.
- special discussions on hot subjects. E.g. a one day session on disorder was organized by P. Leboeuf, with talks given by participants and special guests.

In addition, we organized a four-day conference on quantum gases at Ecole normale supérieure (29 rue d'Ulm) and Institut Henri Poincaré, which was also a Ecole thématique of CNRS, and which presented a complete and high-level instantané of the state of the art of the field, both for theory and experiments. There were 33 invited talks, a discussion session on p-wave superfluidity, and posters so has to allow younger people to express themselves.

The materials of the lectures, seminars, and conference talks one can find on the web site of the trimester.

Participation to the trimester was extensive. We were forced to accept only 140 people among the applicants from abroad, to match the available desk space at IHP (which was saturated in the weeks prior to and posterior to the conference), and also to match our budget (considering the fact that each regular participant from outside of Paris and Ile de France received a *per diem* of 50 euros). We note that there was an intensive participation of local French people to the workshop, in particular from the groups of IFRAF (Francilien Institute of cold atoms) and Ecole normale supérieure. For the conference, there was no registration fees and we had more than 250 participants.

The budget of the workshop was consisting of 190 keuro for supporting regular participants and providing an extra support for invited lecturers and conference speakers, and for some cultural events. We also obtained 10 months of professor positions from universities of Paris/Ile de France, two 3-month positions from CNRS for young researchers of a postdoctoral age, and six 3-month positions from EU for PhD students. The mentioned 190 keuro were given to us by IHP (35 keuro), by IFRAF (85 keuro), by the European Science Foundation (ESF, 40 keuro from the QUDEDIS programme), by the European network INTERCAN (20 keuro), and by Ecole thematique programme (10 keuro).

Scientific life during the workshop was also intense, with numerous discussions among the participants. We had a positive feedback from the participants, in particular from the 6 PhD students and the 2 researchers who were invited for the total, three-month duration of the workshop, thanks to the above mentioned 6 European Marie Curie grants and 2 CNRS guest researcher positions. Many participants asked us to organize a similar event in the coming years. Social life was also not neglected: there was a weekly social dinner open to all regular participants (organized by I. Carusotto and F. Fumarola), and a series of more select dinners for guest lecturers (organized by G. Shlyapnikov). Everyday there was a coffee break at 16:00, provided by IHP and accompanied by a lot of informal discussions.

For the practical organization, we benefited a lot from the efficiency of Sylvie Lhermitte, the manager of centre Emile Borel, and from other administrative people, in particular Nitdavanh Sriratanakoul, Isabelle Duc and Célia Chauveau. The IHP complex, including the computer system, is functioning in a very satisfactory way and this has contributed a lot to the

success of the event. Since a substantial fraction of the budget was covered by IFRAF, we also took advantage of the administrative people of IFRAF, Nicole Neveux and Françoise Tarquis, in particular for the reimbursement of expenses of participants and for the reimbursement of some of the cultural events.

We would like to acknowledge a large support to the workshop by the director of IFRAF Michèle Leduc and the vice-director of IHP Alain Comtet. This is thanks to Michèle that we eventually were able to sponsor participants on a reasonable level, and it is owing to the efforts of Alain that we got 6 Marie Curie grants for PhD students from EU and that in critical situations we got the necessary space for lectures/seminars. It will be honest to also mention that the idea of having the trimester Quantum Gases belongs to Alain Comtet and dates back to the end of 2003. So, we were preparing this successful event during 3.5 years.

We do not have comments to IHP or to other organizations which were supporting our workshop, except for the fact that we are grateful to them for hospitality and support. Our general complain is related to the heavy administrative system which is placed on IHP and, hence, on us from above. It takes a very long time to prepare all required documents for the reimbursement of participants (many of them are really unnecessary), and then the heavy administrative machine still causes long delays with the reimbursement, etc. We understand that our report will be read by people who are not able to modify this machinery themselves. Nevertheless, we hope that if they join their voice to ours, all together we can still do something to make the administrative system less heavy.