

SCIENTIFIC REPORT

Third International Workshop
Theory of Quantum Gases and Quantum Coherence
29 October – 2 November 2005
Cortona (Italy)

Summary

Since the achievement of Bose-Einstein condensation (BEC) of atomic gases and subsequently of degenerate and superfluid atomic Fermi gases, ultracold atomic gases have become a very versatile testing ground for quantum many-body theories and have stimulated experimentalists to devise new techniques. In the last few years, the connection between the atomic and the condensed-matter physics fields have become stronger and nowadays includes scientists and research topics from both areas. In this regard, the Workshop on “*Theory of Quantum Gases and Quantum Coherence*” held in Cortona (Italy) from October the 29th to November the 2nd 2005 have brought together leading senior scientists and young researchers both from theory and experiments on degenerate quantum gases and condensed-matter physics.

The scientific programme of the workshop promoted the collaboration between the best researchers in the field of degenerate quantum gases and coherence phenomena and those from the more traditional field of condensed-matter physics. The Workshop hosted 26 seminars and more than 60 poster contributions dedicated to an audience composed largely of young scientists. The expertise of senior speakers favoured discussions and scientific exchanges between participants during and after the seminar hours as noticed in the large number of questions raised during the talks and the many discussion groups gathering in the spare time. The experimental talks provided information about the experimental feasibility and limits of the theoretical predictions and suggested new theoretical challenges.

The workshop has been a great success and above all it has been very important to stimulate collaborations in the rapidly evolving field of quantum degenerate atoms and to provide new insights in future programmes of research.

Description of the scientific content of and discussion at the event

Similar to the first and second editions of the Workshop held in Salerno in 2001 and in Levico in 2003, the Cortona 2005 Workshop was aimed at young researchers, i.e., PhD students, post-docs and assistant professors. The format of the Workshop involved overview lectures given by senior scientists that provided a general overview of the topic of each session. The overview lectures were followed by more specialised talks of current research given by young researchers.

The Cortona BEC 2005 Workshop explored theoretical aspects in the field of ultracold quantum gases in connection with the field of condensed-matter physics. Due to the strong nexus between the theoretical and experimental progress in this field, the seminars were not restricted to the theory of quantum gases but also covered some of the recent experiments. The included topics were:

- Correlations and new states of ultracold matter
- Quantum phases and quantum-phase transitions
- Fermionic superfluidity and the BCS-BEC crossover in atomic gases
- Disordered systems and the interplay between disorder and interactions
- Quantum state engineering

In addition to the lectures and specialised talks, a whole afternoon was dedicated to a poster session with more than 60 original contributions. The friendly atmosphere of the Workshop offered an ideal opportunity to discuss very hot themes of research providing new insights in the future developments of the field. Furthermore, the Workshop has promoted and stimulated contacts and interdisciplinary interchanges between scientists coming from different areas of physics: Atomic and Molecular Physics, Quantum Optics, and Condensed Matter.

Assessment of the results and impact of the event on the future direction of the field

In the last few years, cold atoms have been increasingly used as a laboratory to investigate the analogue of condensed-matter physics with atomic gases. In this edition of the workshop, the selection of participants and speakers has been done having in mind this increasing connection between the cold atoms and condensed-matter communities. In particular, the Advisory Committee has given important suggestions to prepare a scientific programme that maintained the equilibrium between the two fields while keeping quantum gases as the main focus of the workshop. Moreover due to the strong nexus between the theoretical and experimental progress in this field, the seminars have not been restricted to the theory but have also covered some of the recent experiments. In particular, the workshop hosted talks on current experiments related to the Anderson localisation of matter with Bose-Einstein condensates in quasi-one-dimensional geometries, the BCS-BEC crossover on fermionic atoms and the Berezinskii-Kosterlitz-Thouless (BKT) transition in two-dimensional Bose-Einstein condensates. These have mapped the main directions of the scientific discussions. Indeed, many participants

have given active contributions during the seminars as each talk has been followed by a large number of relevant questions and long discussions during the breaks. Many interesting open directions have been explored during the Workshop like, for instance, how to detect the Bose glass state or the presence of correlated vortices and anti-vortices in a two-dimensional Bose gas.

At present, experimentalists are able to realize one- and two-dimensional systems with periodic lattices with or without disorder, with weak or strong interactions, and thus theoretical models that were considered simply as “toy-models” in the past can now be reproduced in the laboratory. Therefore, we believe that the future directions of the field shall include the use of cold atoms (i) as a test of quantum theoretical models (*e.g.*, BKT transition, the crossover between the BCS and the BEC of composite bosons), (ii) as theoretical and experimental tools for the understanding of open questions in condensed-matter theory (*e.g.*, the competition between disorder and interactions) and (iii) for the progress on quantum computing.

In summary, the choice of the scientific programme and the active contributions of participants have made this workshop a success. Thanks to an agreement with the editors of “Journal of Physics B: Atomic, Molecular, and Optical Physics”, the contributions presented at the Workshop will be considered for publication in a dedicated section of the journal, due to be published in June 2006. Due to the success of the workshop and to the very positive feedback from all participants, it is worth considering to organise a fourth edition of the workshop, most probably in the late spring of 2008.

Final programme of the meeting

The final programme of the Workshop was the following:

- **Saturday, October the 29th**
Arrival, registration and welcome dinner.
- **Sunday, October the 30th**
Morning Session – QUANTUM PHASES

8:30		Opening	
8:45	Lecturer	Rosario Fazio	Quantum phase transitions in optical lattices
9:30	Speaker	Olivier Parcollet	Interaction-induced adiabatic cooling and antiferromagnetism of cold fermions in optical lattices
10:05	Speaker	Michael Köhl	Strongly interacting fermions in optical lattices
10:40		Coffee break	
11:10	Speaker	Corinna Kollath	Spin-charge separation in cold Fermi gases: a real-time analysis
11:45	Speaker	Matthias Vojta	Quantum criticality and exotic phases in condensed matter
12:20	Speaker	Henning Fehrmann	Quantum gases in the trimerised Kagomé lattice

Afternoon Session – QUANTUM STATE ENGINEERING

15:00	Lecturer	Fabrizio Illuminati	Quantum State Engineering
15:45	Speaker	Jacob Sherson	Entanglement and quantum memory with macroscopic gas samples
16:20	Speaker	Giovanna Morigi	Extracting atoms on demand with lasers
16:55		Coffee break	
17:25	Speaker	Andrew Daley	Fault-tolerant dissipative preparation of atomic quantum registers with fermions
18:00	Speaker	Ana María Rey	Extended fermionization of 1D bosons in optical lattices

- **Monday, October the 31st**

Morning Session – DISORDERED SYSTEMS

9:00	Lecturer	Thierry Giamarchi	Disordered quantum systems
9:45	Lecturer	Robin Kaiser	Coherence of waves in random media: coherent backscattering of light by cold atoms
10:30		Coffee break	
11:00	Speaker	Laurent Sanchez-Palencia	Ultracold Fermi-Bose mixtures in inhomogeneous and disordered optical lattices
11:35	Speaker	Jessica Lye	Experiments with condensates in random optical potentials
12:10	Speaker	Walter Hofstetter	Disorder versus interaction in ultracold atomic systems

Afternoon Session – POSTER DISCUSSION

15:00 – 17:00	Poster session
17:00 – 17:30	Coffee break
17:30 – 19:00	Poster session

- **Tuesday, November the 1st**

Morning Session – FERMIONIC SUPERFLUIDITY

9:00	Lecturer	Carlos Sá de Melo	Evolution from BCS to BEC superfluidity in dilute Fermi gases
9:45	Speaker	Cindy Regal	Studying the BCS-BEC crossover regime with a Fermi gas of atoms
10:20		Coffee break	
10:50	Speaker	Pierbiagio Pieri	Diagrammatic theory for the BCS-BEC crossover
11:25	Speaker	Johannes Hecker Denschlag	BEC-BCS crossover with an ultracold gas of ^6Li atoms
12:00	Speaker	Giuliano Orso	Superfluid Fermi gas in a 1D optical lattice

Afternoon Session – FLUCTUATIONS AND CORRELATIONS IN QUANTUM GASES

15:00	Lecturer	Gordon Baym	New states of quantum gases
15:45	Speaker	Francesca Federici	Superradiant scattering from hydrodynamic vortices
16:20	Speaker	Sabine Stock	Observation of phase defects in 2D Bose-Einstein condensates
16:55		Coffee break	
17:25	Speaker	Paolo Pedri	Bose-Einstein condensate of dipolar gases
18:00	Speaker	Nicolas Regnault	Composite fermionization of bosons in rapidly rotating atomic traps
18:35		Closing remarks	

- **Wednesday, November the 2nd**

Departure.

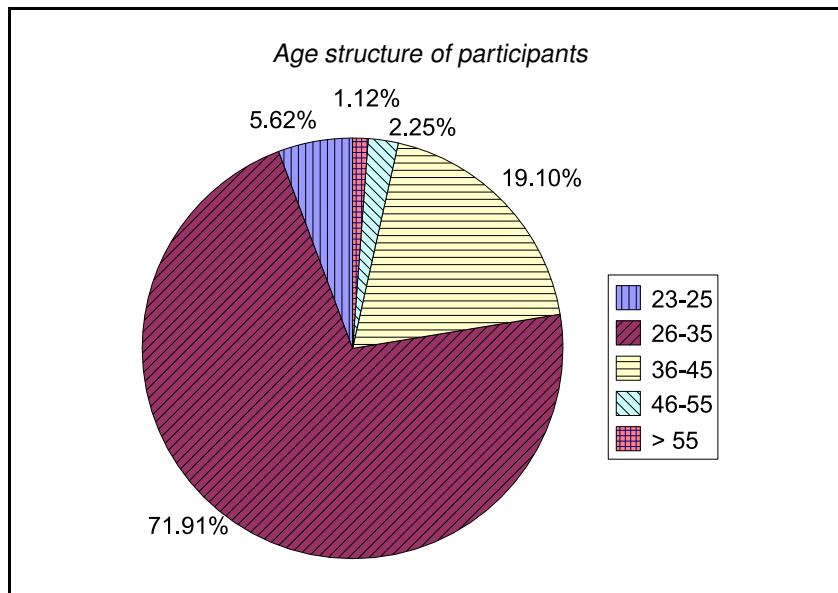
We enclose with the hard copy of the present report a copy of the book of abstracts of the Workshop, where the list of posters and the abstracts of all the scientific contributions can be found. Notice that the participants Guilleumas, Lukin, Pachos, and Sinha

included in the printed book cancelled their participation at the very last moment after the book was already printed, while participants Mazzarella and Bahktiari attended the Workshop but were not included in the printed book. The full and up-to-date list of participants has been entered in the database of ESF for the Workshop as requested.

Statistical information on participants

The total number of participants in the Workshop has been 89 with most of them being less than 35 years old. To make a statistics on the age of the participants, we considered the following age ranges:

- 23–25,
- 26–35,
- 36–45,
- 46–55,
- older than 55 years



This shows that more than 3/4 of the participants were actually younger than 35. They correspond to PhD students and post-docs.

In the statistics on the origin of the participants, we made the difference between the country of nationality and that of the working place (hereafter called affiliation). We analysed first all the countries separately and then looked at the percentage on a geographical basis, grouping the different countries as follows:

- western Europe: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Luxembourg, Spain, Switzerland, The Netherlands, and United Kingdom;
- eastern Europe: Hungary, Poland, and Russia;

- Americas: Argentina, Brazil, Canada, Colombia, and USA;
- Asia: Bangladesh, China, Kazakhstan, India, Iran, Israel, Japan, and Turkey;
- Oceania: Australia and New Zealand.

