

# Scientific Report on Les Houches Predoctoral School in Statistical Physics

August 27<sup>th</sup>-September 6<sup>th</sup> 2007

The school was attended by 52 students of 15 different nationalities. The first week was devoted to an introduction to statistical mechanics at a graduate level. Two 1h30 lectures were given each morning, from Monday to Friday. Exercise sessions on each course (also 1h30 each) took place in the afternoon. Furthermore three 1h seminars were given by invited speakers.

The first course, on equilibrium statistical mechanics, was given by George Batrouni (Institut Non Linéaire, Nice). This course covered first the basics of quantum statistical mechanics of indistinguishable particles: calculation of the partition function for non interacting bosons and fermions and main physical properties at low temperatures. Then the lectures moved on to more advanced subjects, such as Bose-Einstein condensates and their superfluid properties. Finally the Quantum Monte Carlo method was explained in some detail, and recent applications were discussed. The exercise sessions were led by Frédéric Hébert (Institut Non Linéaire, Nice).

The second course, on non equilibrium statistical mechanics, was given by Michel Le Bellac (Institut Non Linéaire, Nice). The first two lectures were devoted to a review of basic tools of non equilibrium statistical mechanics: linear response, Brownian motion, Langevin equation, (Pauli) master equation. The following lectures dealt with the derivation of quantum master equations from the Schrödinger equation, and some of their applications to quantum optics and to quantum Brownian motion. Finally, some recent developments: the Crooks and Jarzynski equalities and the Gallavotti-Cohen fluctuation theorem were examined in the last lecture. M. Le Bellac led the exercise sessions.

The first two seminars of the week were given by Alex Hansen (NTNU, Trondheim), who reviewed the problem of fracture, and the third one by Richard Scalettar (U.C. Davis), who spoke about the Hubbard model and its applications to various problems of condensed matter physics.

The second week was devoted to more specialized lectures, which made use of the material discussed during the first week. There were also three 1h seminars given by invited speakers. The first set of lectures was delivered by Yvan Castin (LKB, ENS Paris). Castin examined various problems linked to Bose-Einstein condensation. After a review of the basic tools (contact potential, Gross-Pitaevskii equation, Bogoliubov approximation), Castin moved on toward recent research topics such as one dimensional and two-dimensional condensates, which are at present hot topics, both experimentally and theoretically. The exercise sessions were led by Félix Werner (LKB, ENS Paris).

Marco Wölki (University of Duisburg) lectured on models of non equilibrium statistical mechanics applied to traffic. He discussed in detail the one-dimensional asymmetric jump models by deriving the corresponding master equations, and in particular he examined the matrix solution of the Derrida/Evans/Hakim/Pasquier model. These models were then applied to the formation of one-lane traffic jams with periodic or open boundary

conditions and compared to realistic situations. Generalizations to multi-lane problems were briefly examined. The exercise sessions were also lead by Marco Wölki.

The first two seminars of the second week were delivered by Michel Brune (LKB, ENS Paris), who reviewed the beautiful experiment performed at the ENS, in which they are able to count the number of photons in a superconducting cavity. Brune then discussed the effects of decoherence, making the link with the course of the first week. Finally Dries van Oosten gave the last seminar on correlations in optical lattices; Mott to insulator transition, HBT effects for atoms, tunneling and superlattices.

The school was extremely lively, with many questions asked by the students during the lectures and after the lectures. Students also asked many questions on their ongoing research and helpful advice could be provided in many cases. There is no doubt that the school was a great success.

Notes for almost all the lectures, seminars and discussion sessions are posted on the web page of the school: <http://statphys07.inln.cnrs.fr/>.

Week 1: (Monday Aug 27 - Friday Aug 31)

Monday:

- 08:45 – 10:15 Quantum Statistical Mechanics lecture (Batrouni)
- 10:30 – 12:00 Non-Equilibrium Statistical Mechanics lecture (Le Bellac)
- 15:00 – 16:00 SEMINAR: Statistical Physics of fracture and breakdown I (Hansen)
- 16:15 – 17:15 Quantum Statistical Mechanics exercises (Hébert)
- 17:30 – 18:30 Non-Equilibrium Statistical Mechanics exercises (Le Bellac)

Tuesday:

- 08:45 – 10:15 Non-Equilibrium Statistical Mechanics lecture (Le Bellac)
- 10:30 – 12:00 Quantum Statistical Mechanics lecture (Batrouni)
- 15:00 – 16:30 Non-Equilibrium Statistical Mechanics exercises (Le Bellac)
- 17:00 – 18:30 Quantum Statistical Mechanics exercises (Hébert)

Wednesday:

- 08:45 – 10:15 Quantum Statistical Mechanics lecture (Batrouni)
- 10:30 – 12:00 Non-Equilibrium Statistical Mechanics lecture (Le Bellac)
- 15:00 – 16:00 SEMINAR: Forty Years of the Hubbard Model: From the solid state to cold atoms on optical lattices (Scalettar)
- 16:15 – 17:15 Quantum Statistical Mechanics exercises (Hébert)
- 17:30 – 18:30 Non-Equilibrium Statistical Mechanics exercises (Le Bellac)

Thursday:

- 08:45 – 10:15 Non-Equilibrium Statistical Mechanics lecture (Le Bellac)
- 10:30 – 12:00 Quantum Statistical Mechanics lecture (Batrouni)
- 15:00 – 16:30 Non-Equilibrium Statistical Mechanics exercises (Le Bellac)
- 17:00 – 18:30 Quantum Statistical Mechanics exercises (Hébert)

Friday:

- 08:45 – 10:15 Quantum Statistical Mechanics lecture (Batrouni)
- 10:30 – 12:00 Non-Equilibrium Statistical Mechanics lecture (Le Bellac)
- 15:00 – 16:00 SEMINAR: Statistical Physics of fracture and breakdown II (Hansen)
- 16:15 – 17:15 Quantum Statistical Mechanics exercises (Hébert)
- 17:30 – 18:30 Non-Equilibrium Statistical Mechanics exercises (Le Bellac)

## Week 2: (Monday Sept 3 - Friday Sept 7)

“Field Theory Methods and Statistical Mechanics of Cold Bosonic and Fermionic Atoms” = Cold Atoms

“Statistical Physics of Dissipative Systems: Granular systems and traffic” = Granular systems and traffic

### Monday:

- 08:45 – 10:15 Cold Atoms lecture (Castin)
- 10:30 – 12:00 Granular systems and traffic lecture (Schreckenberg)
- 15:00 – 16:00 SEMINAR: Dissipation, quantum measurement and decoherence I (Brune)
- 16:15 – 17:15 Cold Atoms exercises (Werner)
- 17:30 – 18:30 Granular systems and traffic exercises (Schreckenberg)

### Tuesday:

- 08:45 – 10:15 Granular systems and traffic lecture (Schreckenberg)
- 10:30 – 12:00 Cold Atoms lecture (Castin)
- 15:00 – 16:00 SEMINAR: Dissipation, quantum measurement and decoherence II (Brune)
- 16:15 – 17:15 Granular systems and traffic exercises (Schreckenberg)
- 17:30 – 18:30 Cold Atoms exercises (Werner)

### Wednesday:

- 08:45 – 10:15 Cold Atoms lecture (Castin)
- 10:30 – 12:00 Granular systems and traffic lecture (Schreckenberg)
- 15:00 – 16:00 SEMINAR: Exploring strongly correlated quantum physics in optical lattices (van Oosten)
- 16:15 – 17:15 Cold Atoms exercises (Werner)
- 17:30 – 18:30 Granular systems and traffic exercises (Schreckenberg)

### Thursday:

- 08:45 – 10:15 Granular systems and traffic lecture (Schreckenberg)
- 10:30 – 12:00 Cold Atoms lecture (Castin)
- 15:00 – 16:30 Granular systems and traffic exercises (Schreckenberg)
- 17:00 – 18:30 Cold Atoms exercises (Werner)

### Friday:

- 08:45 – 10:15 Cold Atoms lecture (Castin)
- 10:30 – 12:00 Granular systems and traffic lecture (Schreckenberg)