

## **REPORT ON**

# **II Summer School on Statistical Physics of Complex and Small Systems**

Benasque (Huesca), Spain, September 3-14, 2011

### **SUMMARY:**

The main goal of this summer school was to provide PhD students working on Complex and Small Systems, a solid background on Statistical Physics methods and techniques that can be used in their research. The school also pretended to show the students new fields of active research in order to broad their views on the discipline they are working on.

The school took place at the “Centro de Ciencias de Benasque Pedro Pascual” at the Pyrenean village of Benasque, Huesca, Spain. The Centre provided the facilities needed for the development of different courses: several spaces for classes, hands-on sessions and discussions. It is also prepared with a computer room for some of the practical session. The centre also provided the administrative support (accommodation, web page, computer system manager, etc) for the efficient management of the courses.

The school was held for two week and six courses were given (three each week). A detailed description of the courses is given below. 27 students coming from 6 different countries and 7 nationalities were selected (from 45 applications) and attended to the School. During the school 36 hours of lectures and 18 practical classes (hands-on sessions) were given. Besides, the students had the opportunity of showing their work to their school mates in a special session.

Finally, 25 students were granted with the accommodation and meals expenses.

## DESCRIPTION OF THE SCIENTIFIC CONTENT.

The school was divided in six courses (three each week). Each course consisted of six hours of lectures and one or two hands-on sessions (1,5 - 2 hours). The courses have been:

### First Week:

- *Stochastic Thermodynamics.*

Massimiliano Esposito, Université Libre de Bruxelles, Belgium

- *Evolution and Statistical Mechanics.*

José A. Cuesta, Universidad Carlos III de Madrid, Madrid, Spain.

- *Statistical Physics of Networks and Proteins.*

Paolo de los Rios, EPF de Laussane, Laussane, Switzerland.

### Second Week:

- *Systems Biology.*

Marta Ibañes, UB, Barcelona, Spain.

- *Neurobiology and Behavior.*

Gonzalo G. de Polavieja, Instituto Cajal (CSIC) Madrid, Spain.

- *Experiments in Soft Matter.*

Francesc Sagues, Universitat de Barcelona, Barcelona, Spain.

Next, a brief description of each course is given:

### *Stochastic Thermodynamics.*

Dr. Esposito has reviewed, in a very pedagogical view, the formalism of the called “Stochastic Thermodynamics” concluding with the derivation and discussion of the fluctuation theorems in the context of non-equilibrium statistical mechanics.

In the “hands-on” session, a number of exercises and details left in the theoretical lectures were solved.

### *Evolution and Statistical Mechanics.*

Professor Cuesta made a review of the state of art in the application of statistical mechanics to the field of evolutionary dynamics. He dealt with the modelling and mathematical description of phenomena of replication, competition, mutation and interaction (as studied in the frameworks of population dynamics and game theory).

In the “hands-on” session, a number of exercises and details left in the theoretical lectures were solved.

### ***Statistical Physics of Networks and Proteins.***

Professor de los Rios course was divided into two parts. First, he gave a review of main definitions and characterization of complex networks. Then, a revision of the main properties of proteins and the problems that their study poses to physics (mainly the so-called protein folding problem) was given. Finally, the approach, from the point of view of the network models, to all these problems was discussed.

In the “hands-on” session, a number of exercises and details left in the theoretical lectures were solved. Numerical algorithms for network building were discussed.

### ***Systems Biology.***

Dr. Ibañes made an introduction to the phenomenology of gene regulation in cells. After that, she discussed the framework in which the system biology is built. She described the main and simple genetic circuits and solved them in the frame of nonlinear dynamical systems (finding fixed points, making linear stability analysis etc...). Finally, she discussed the problem of pattern formation in the field of development biology. All its lectures were plenty of biologically motivated examples.

Practical sessions were devoted to the computer analysis of the equations corresponding to some of the genetic circuits shown in the lectures.

### ***Neurobiology and Behavior.***

Dr. Polavieja made a revision of main experimental facts and problems in the field of neurobiology and the method to approach them from a physical approach. He reviewed the main models of neural activity (Hodgkin-Huxley, FitzHugh-Nagumo, etc...) as well as experimental methods to test them (some of them developed in his lab). He concluded with the explanation of models of collective behaviour and proposed experiments to corroborate them.

In hands-on sessions, Dr. Polavieja conducted several experiments of social behaviour using the students as agents.

### ***Experiments in Soft Matter.***

Professor Sagués devoted its course to some problems in soft-matter physics mainly from an experimental point of view. He focused on Langmuir films and liquid crystals as example of general phenomena of self-assembly and self-organization in soft-matter. He finished with an ample discussion on the concept of chirality in the fields of biology and defects in liquid crystal structures. During its lessons, he made some experimental demonstrations to illustrate some points of the theoretical talks.

For hands-on session, Professor Sagués organised working groups to read and discuss seminal papers in the field. The activity finished with a general sharing of conclusions

### ***Students Talks Session***

Students were given the opportunity of giving a short talk (5 min.) of their results or their projects for the PhD work. Most of the attendants (25) took advantage of this opportunity. The session was especially fruitful since it opened the way to discussion between students and professors along the course.

A detailed of the talks is given below in the final program.

## **ASSESSMENT OF THE RESULTS AND IMPACT OF THE EVENT.**

The main objectives of School were successfully fulfilled:

- To provide the students a complementary formation, at the PhD level, valuable for their research work.
- To create a space for sharing experience and knowledge between lectures and students as well as students themselves. The lectures given by the students were especially beneficial for this goal.
- To apply the knowledge acquired at the theoretical lectures. The hands-on sessions allowed students to deep and put in practise the concepts of the formal lectures. These sessions also facilitated the close interaction between lectures and students.

Students showed the organizers their satisfaction regarding the organization, the scientific contents and the format of the School

Regarding the impact of the School, the success of this edition and the previous one in Mallorca (Spain) allows to predict the continuity of these kind of events. In fact it is planned to continue with the third edition of the School next year in Cantabria (Spain).

Finally, more information about the contents and development of the School (including pictures) can be found in: <http://benasque.org/2012gss/>

# FINAL PROGRAMME OF THE MEETING.

## Monday, September 03

- 09:45h **Arrival to Benasque**
- 15:30h **Evolutionary Dynamics**  
José Cuesta
- 16:30h [Stochastic Thermodynamics](#)  
Massimiliano Esposito
- 18:00h **Statistical Physics of Networks and Proteins**  
Paolo de los Rios

## Tuesday, September 04

- 09:30h [Stochastic Thermodynamics](#)  
Massimiliano Esposito
- 11:15h **Statistical Physics of Networks and Proteins**  
Paolo de los Rios
- 12:30h [Evolutionary Dynamics](#)  
José Cuesta
- 15:30h **Work in groups:**  
**G1 (Stochastic Ther.)**  
**G2 (Evolution)**  
**G3 (Networks & Prot.)**
- 18:00h **Work in Groups**

## Wednesday, September 05

- 09:30h [Evolutionary Dynamics](#)  
José Cuesta
- 11:15h [Stochastic Thermodynamics](#)  
Massimiliano Esposito
- 12:30h **Statistical Physics of Networks and Proteins**  
Paolo de los Rios
- 15:30h **Work in groups:**  
**G1 (Stochastic Ther.)**  
**G2 (Evolution)**  
**G3 (Networks & Prot.)**
- 18:00h **Work in Groups**

## Thursday, September 06

- 09:30h **Statistical Physics of Networks and Proteins**  
Paolo de los Rios
- 11:15h [Evolutionary Dynamics](#)  
José Cuesta
- 12:30h [Stochastic Thermodynamics](#)  
Massimiliano Esposito
- 15:30h **Work in groups:**  
**G1 (Stochastic Ther.)**

**G2 (Evolution)**  
**G3 (Networks & Prot.)**

- 18:00h **Work in Groups**

### **Friday, September 07**

- 09:30h [Stochastic Thermodynamics](#)  
Massimiliano Esposito
- 11:15h **Statistical Physics of Networks and Proteins**  
Paolo de los Rios
- 12:30h **Evolutionary Dynamics**  
José Cuesta

### **Monday, September 10**

- 09:30h **Students Presentations**
- 15:30h [Neurobiology and Behavior](#)  
Gonzalo G. de Polavieja
- 16:30h **Systems Biology**  
Marta Ibañes
- 18:00h [Experiments in Soft Matter](#)  
Francesc Sagues

### **Tuesday, September 11**

- 09:30h **Systems Biology**  
Marta Ibañes
- 11:15h [Experiments in Soft Matter](#)  
Francesc Sagues
- 12:30h [Neurobiology and Behavior](#)  
Gonzalo G. de Polavieja
- 15:30h **Work in groups:**  
**G1 (Syst. Biol.)**  
**G2 (Neurobiol.)**  
**G3 (Soft Matter)**
- 18:00h **Work in Groups**

### **Wednesday, September 12**

- 09:30h [Neurobiology and Behavior](#)  
Gonzalo G. de Polavieja
- 11:15h **Systems Biology**  
Marta Ibañes
- 12:30h [Experiments in Soft Matter](#)  
Francesc Sagues
- 15:30h **Work in groups:**  
**G2 (Neurobiol.)**  
**G3 (Soft Matter)**

Download Systems Biology ode files:

- [G1 \(Syst. Biol.\)](#)
- 18:00h **Work in Groups**

### **Thursday, September 13**

- 09:30h [Experiments in Soft Matter](#)  
Francesc Sagues
- 11:15h [Neurobiology and Behavior](#)  
Gonzalo G. de Polavieja
- 12:30h **Systems Biology**  
Marta Ibañes
- 15:30h **Work in groups:**  
**G1 (Syst. Biol.)**  
**G2 (Neurobiol.)**  
**G3 (Soft Matter)**
- 18:00h **Work in Groups**

### **Friday, September 14**

- 09:30h **Systems Biology**  
Marta Ibañes
- 11:15h **Experiments in Soft Matter**  
Francesc Sagues
- 12:30h [Neurobiology and Behavior](#)  
Gonzalo G. de Polavieja
- 13:40h **Closing**

## MONDAY SEPTEMBER 10, STUDENT SHORT TALKS.

### 9:30 -10:45

- **BRETT, Tobias:** Complex Systems and Statistical Physics Group, University of Manchester, School of Physics and Astronomy, Theoretical Physics Division. *Stochastic processes with delay.*
- **CARDILLO, Alessio:** University of Zaragoza. *Evolutionary Games, Networks and More.*
- **CONSTABLE, George:** University of Manchester. *Stochastic adiabatic reduction (or nullcline conditioning).*
- **DOMÍNGUEZ, Virginia:** Facultad de Ciencias de Granada. *Food-webs.*
- **DUQUE RODRÍGUEZ, Juan Ramón:** Universidad Politécnica de Madrid. *Olfactory search.*
- **FERNÁNDEZ DEL RÍO, Ana:** Departamento Física Fundamental (UNED). *Interdependent choices and coupled Ising models.*
- **FONT-CLOS, Francesc:** Centre de Recerca Matemàtica. *Belief propagation to model metabolism network.*
- **GODOY LORITE, Antonia:** Universitat Rovira i Virgili. *Long term evolution in complex networks.*

### 10:45- 11:10 Coffee Break.

### 11:10 – 12:25

- **GÜELL, Oriol:** Universitat de Barcelona. *Predicting effects of structural stress in genome –reduced bacterial metabolism.*
- **HAYRAPETYAN, Gor:** Yerevan State University. *ssRNA thermodynamics: constrained annealing approach.*
- **IBÁÑEZ MARCELO, Esther:** Centre de Recerca Matemàtica. *Genetic Networks.*
- **MENICHETTI, Giulia:** University of Bologna. *Applications of network entropy to gene expression time series data.*
- **NESIC, Svetozar:** Universidad Carlos III de Madrid. *Intrinsic noise on Fisher fronts.*
- **PEARCY, Nicole:** Nottingham Trent University. *Unravelling the complexity of metabolic networks.*
- **PEREZ-CARRASCO, Ruben:** Facultat de Física - Universitat de Barcelona. *Mechano-chemistry of rotating molecular motors.*
- **REQUEJO, Rubén J.:** Statistical Physics Group, Universitat Autònoma de Barcelona. *Cooperation, resources and destructions.*

### 12:30- 13:45

- **ROLDAN, Edgar:** Universidad Complutense de Madrid. *Measuring irreversibility to distinguish between active and passive processes.*
- **ROTONDO, Ernesto Federico:** Universidad Nacional General Sarmiento. *Biological systems and noise-induced transitions.*
- **SAGARRA PASCUAL, Oleguer:** Universitat de Barcelona, Departament de Física Fonamental. *Exploring urban structure through GPS traces: a network approach.*
- **SÁNCHEZ-TALTAVULL, Daniel:** Centre de Recerca Matemàtica. *Population dynamics in HIV-1 infection.*
- **SANTIAGO GONZALEZ, Ibon:** MIT. *DNA nanomachines.*
- **TAPIA-ROJO, Rafael:** Universidad de Zaragoza. *Mesoscopic model for the free energy analysis of DNA sequences.*
- **VILLA MARTÍN, Paula:** Universidad de Granada. *Influence of network topology in first order phase transitions.*
- **VIVO, Edoardo:** Universidad Carlos III de Madrid. *Anisotropy and scaling relations in surface growth models*