Editorial*

The present extensive volume provides a snapshot, yet fairly comprehensive survey of the most recent and relevant developments in statistical physics and its applications in the physical sciences and beyond. Emphasis has been given to strike a balance between traditional and novel topics, and by giving a voice to both well-established and emerging research communities the world over.

The contributions are based on the plenary and invited lectures given at the occasion of the premier venue for this scientific community, the triennial IUPAP conference STATPHYS, the 23rd edition of which had been held in Genova, Italy from July 9-13, 2007. For more information about the conference and the other contributions, oral or poster, the reader is cordially invited to consult the conference page: `http://www.statphys.org/`.

The published papers include the reviews by the Boltzmann award winners, Kurt Binder and Giovanni Gallavotti, and a lively transcription of the laudatio ceremonial presentation of the Young Scientist Award and the Boltzmann Award is appended further below. As electronic supplement to this editorial, the reader will further find the opening address by David Mukamel, Chairman of the IUPAP C3 Commission on Statistical Physics, as well as the list of corresponding committees.

For the considerable effort in putting this special issue together we would like to thank the many colleagues that have acted as authors and referees, or have contributed in many other ways to make out of this volume a lasting source of reference for the years to come.

The guest editors

Vittorio Loreto
Luciano Pietronero
Stefano Zapperi

Boltzmann Award Session

Michael E. Fisher, Chairman of the Session

It is my privilege and responsibility now to chair the Awards Session of STATPHYS 23 here in the venerable port city of Genoa.

This year, for the first time, two Young Scientist Awards in Statistical Physics will be presented. This development, recognizing the valuable role to be played in science by encouraging younger colleagues with fresh ideas and perspectives, is surely to be welcomed. We will have the opportunity to hear the two awardees, Giulio Biroli and Tomohiro Sasamoto, present talks this Friday morning (in Topical Sessions 9D and 3D, respectively).

Following the Young Scientist Awards we will witness the presentation of two Boltzmann Medals. These represent the prime professional tribute for outstanding contributions to our noble science, Statistical Physics, founded, let us recall, over a century ago by Maxwell, Boltzmann, and Gibbs. The Commission on Statistical Physics of the International Union of Pure and Applied Physics established these awards thirty-three years ago. The first medal was presented in Budapest at STATPHYS 12 in 1975 to Kenneth G. Wilson, then my close colleague in Cornell University.

This year we celebrate as medalists Kurt Binder of the Johannes-Gutenberg University of Mainz and Giovanni Gallavotti of the University of Rome "La Sapienza".

David Mukamel, of the Weizmann Institute of Science and Chair of the IUPAP C3 Commission on Statistical Physics, will tell us about all the awards, announce the citations for the awardees and medalists, and make the presentations. After that, it will be my personal pleasure, to offer a few words by way of introduction to Kurt Binder and Giovanni Gallavotti before we hear their lectures. I call now on David Mukamel.

Presentation of the Awards

David Mukamel, Chair of the IUPAP C3 Commission on Statistical Physics

It is my pleasure to introduce the new Young Scientist Award in Statistical Physics. The award has recently been established by The International Union of Pure and Applied Physics (IUPAP) through its C3 Commission on Statistical Physics. It is awarded to young scientists in recognition of specific and outstanding contributions in the broad and diverse field of statistical physics. The award will be presented every three years on the occasion of the STATPHYS conference, where up to three recipients will be selected in each round.

On behalf of the C3 Commission on Statistical Physics I am honored to announce the awardees for 2007, Giulio Biroli from France and Tomohiro Sasamoto from Japan, and congratulate them both.

The citations read:

"The Commission on Statistical Physics of the International Union of Pure and Applied Physics (IUPAP) is pleased to award the Young Scientist Award (2007) to Giulio Biroli for his studies of the thermodynamics and dynamical properties of the glass transition and jamming phenomena."

and

"The Commission on Statistical Physics of the International Union of Pure and Applied Physics (IUPAP) is pleased to award the Young Scientist Award (2007) to Tomohiro Sasamoto for his contributions to the study of non-equilibrium steady states by providing exact solutions to models of driven systems."

Giulio Biroli obtained his PhD at the Laboratoire de Physique Théorique of the École Normale Supérieure in Paris. After finishing his studies in the year 2000 he became a postdoctoral fellow at Rutgers University in the US. In 2002 he became a permanent member of the Service de Physique Théorique in Saclay, France.

The scientific activity of Giulio Biroli has been focused on the thermodynamics and dynamical properties of the glass transition and jamming phenomena. Understanding the intricate behavior of glasses is one of the most challenging objectives of statistical physics. Giulio Biroli in his work and in collaboration with others made remarkable contributions to this field, ranging from theoretical aspects of the glass transition to new experimental findings.

In his studies of the glass transition Giulio, together with others, introduced a new class of kinetically constrained models. These are models of hard core particles whose thermodynamics is trivial but which are characterized by dynamical constraints which result in extremely slow dynamics at high densities. The models were proven to exhibit a dynamical glass transition where above a critical density ergodicity is broken due to the appearance of an infinite spanning cluster of jammed particles. The phenomenology of this transition, which takes place in a

model without disorder, is similar to that found experimentally in glass and jamming transitions.

In another series of studies Giulio Biroli together with others developed theoretical approaches to the glass transition based on Mode Coupling Theory and field theoretical methods to explain how dynamical correlations grow when the glass transition is approached. The major result is a complete quantitative theory of the spatial and temporal critical properties of dynamic correlations, and in particular their critical exponents and scaling functions. In these studies Giulio Biroli and collaborators have developed new theoretical tools and introduced new dynamical response functions in order to measure the growing length scale in glass forming liquids. Experiments based on these studies have subsequently been carried out providing direct experimental evidence for a growing length scale in glass forming liquids.

Giulio Biroli made outstanding and influential contributions to our understanding of the behavior of glassy materials. For these contributions he receives the Young Scientist Award. I now call him to receive the award.

Tomohiro Sasamoto studied at the University of Tokyo and received his PhD in the year 2000. On completing his training he became an Assistant Professor at the Tokyo Institute of Technology. In 2005 he joined the Department of Mathematics and Informatics at Chiba University in Japan, where he has remained since then.

Tomohiro's scientific activity has been focused on non-equilibrium systems, mainly on theoretical studies of non-equilibrium steady states in a large class of driven diffusive systems. Non-equilibrium statistical physics is one of the most challenging areas of theoretical physics, where a general guiding theoretical framework is still lacking. Much of the activity in this field has thus been focused on accumulating concrete, reliable and non-trivial results on specific models which could provide insight into the collective behavior of these complex systems. In his work Tomohiro made remarkable contributions in this direction by providing exact solutions to some models which represent what is believed to be the generic behavior of a broad class of models.

One important contribution of Tomohiro, done while still a student at the University of Tokyo, is his exact solution of the steady states of the one-dimensional Asymmetric Simple Exclusion Process. This is one of the standard idealized models used for probing universal features of non-equilibrium steady states. In spite of considerable attention by both the physics and mathematics communities, exact solutions of the model had been limited to very special cases. Tomohiro's highly sophisticated solution provides us with the phase structure and phase transitions generated by the interplay between two drive mechanisms: one of which originates from difference in chemical potential at the boundaries while the other is induced by a bulk external field.

A second important achievement of Tomohiro is the exact solution of an exclusion process with two species of particles. In this work Tomohiro and coworkers settled

the question of the existence of a phase transition in this intriguing model, demonstrating that the model exhibits sharp crossover behavior rather than a true transition into a phase-separated state.

Tomohiro's work is deep and of great importance from both physical and mathematical points of view. I now call him to receive the award.

As mentioned, the Boltzmann Awards were instituted by the C3 Commission in 1974. They consist of a gilded medal, the front carrying the inscription "Ludwig Boltzmann, 1844-1906", the reverse the name of the recipient. The medals are given every three years in association with the STATPHYS conferences.

The previous winners, now sixteen in number, are: K.G. Wilson (1974), R. Kubo (1977), R.J. Baxter (1980), M.E. Fisher (1983), D. Ruelle and Y. Sinai (1986), L.P. Kadanoff (1989), J.L. Lebowitz and G. Parisi (1992), S.F. Edwards (1995), E. Lieb and B. Widom (1998), B.J. Alder and K. Kawasaki (2001), and E.G.D. Cohen and H.E. Stanley (2004).

This year the Commission resolved to award two separate medals. Thus I am honored, on behalf of the Commission, to present medals to Kurt Binder from Germany and Giovanni Gallavotti from Italy. We extend hearty congratulations to them both and formally proclaim:

"The Boltzmann Medal for 2007 is hereby awarded to Kurt Binder for his leading role in developing computer simulation methods and, in particular, the Monte Carlo method into a reliable and quantitative tool of statistical physics, and for his many central contributions to statistical physics in this context".

and

"The Boltzmann Medal for 2007 is hereby awarded to Giovanni Gallavotti for his fundamental contributions to our precise understanding of equilibrium and non-equilibrium statistical physics, including the development of a constructive renormalization group for phase transitions, dynamical systems, and quantum liquids."

Remarks on the Boltzmann Medalists
by Michael E. Fisher

In the summer of 1970 Mel Green, who had recently left the National Bureau of Standards in Washington, DC for a position at Temple University in Philadelphia, organized a summer school on Critical Phenomena in the glorious Villa Monastero in Varenna on the shores of Lake Como. Among others, four subsequent Boltzmann medalists gave lectures in this Course No. 51 of the International School of Physics of the Italian Physical Society "Enrico Fermi"[1].

And, now, we welcome the first student from the School to win a Boltzmann award, namely, Kurt Binder.

In Varenna I personally met Kurt for the first time: but, as fate would have it, three and a half decades would

Kurt Binder

pass before, in 2005-6, we finally enjoyed a direct collaboration by working with colleagues[2] on the critical dynamics of a binary solution!

In 1970 Kurt had graduated from the Technical University in Vienna, gaining a Ph.D. in 1969, and was a Research Associate in Munich at the Technical University. Later, for sixteen years from 1977, he worked in Jülich (with a professorship in Cologne); since 1983 he has been Professor of Physics in Mainz where his large and dynamic research group has been a training ground for generations of computer simulators who have carried his example and their lessons to universities in Europe and further afield. However, his advice and encouragement for young researchers has extended well beyond those who worked with him in Mainz.

In recognizing the profound influence and exceptional breadth of Kurt's contributions to computational science, it is important to realize the poor shape of numerical simulations when he entered the field in the 1970's: in the words of one expert, they were "associated with results of low-precision, questionable reliability and unknown influence of system size". Kurt Binder changed all that! He was the first to appreciate the significance of finite-size scaling for Monte Carlo simulations and to develop and demonstrate a practical and effective tool-kit. With characteristic astuteness, he highlighted the dimensionless fourth-order cumulant of an order-parameter distribution that is now usually called simply the "Binder parameter". His techniques invigorated the field and led to much reliable quantitative information and many valuable insights regarding phase transitions of both critical and first-order character.

Beyond his technical skills in simulation, and the admirable textbooks he has published, it is important, however, in the words of a colleague, to stress Kurt Binder's role "both historically and to this day, in raising and maintaining the intellectual standards of the computer simulation community". He has achieved this, in particular, via his keen appreciation of the underlying theory and its concepts in any field he has studied. Careful simulations have invariably been coupled with thoughtful analytical considerations. And, if the theory was not fully in place, he has been prepared to develop it! By way of example, I may cite

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[1] See the *Proceedings: Critical Phenomena*, edited by M.S. Green (Academic Press, New York 1979).

[2] Subir K. Das, Jürgen Horbach, and Jan V. Sengers: see Phys. Rev. Lett. **97**, 025702 (2006) and J. Chem. Phys. **125**, 024506 (2006).

his notable work with Pierre Hohenberg in 1972-74 regarding surface critical phenomena summarized beautifully in Vol. 8 (1983) of the Domb and Lebowitz series on *"Phase Transitions and Critical Phenomena"*.

Finally, to illustrate the remarkable range of his work, let me list some of the topics on which Kurt Binder has made significant contributions. These include: wetting and multilayer adsorption; interface delocalization; polymer physics – especially polymer-colloid mixtures and the crossover from mean-field to Ising critical behavior that is controlled by polymer length; the kinetics of spinodal decomposition; spin glasses and structural glasses; the systematic construction of coarse-grained models for "soft materials".

Beyond his research and writing, Kurt has served his community on many boards and committees and, notably, as Chairman of "our" IUPAP Commission!

But the time has come to hear from Kurt Binder himself: he will now tell us how Monte Carlo can reveal the nature of phase equilibria and their transitions.

To set the extensive researches of Giovanni Gallavotti in context, it may be helpful to remind ourselves of the status of statistical mechanics when he began his career.

Giovanni Gallavotti

In the 1960's, stimulated by Onsager's remarkable solution of the planar square Ising model, the serious application of statistical mechanics to study phase transitions became a priority. But how could one be confident of the answers one might derive and their experimental relevance? Might not different ensembles yield different answers? Would virial series or expansions in powers of $1/T$ converge? What should one make of van der Waals and mean-field theories, of spinodals, metastable states, and the Maxwell construction? How should one define surface tension and the thickness of an interface?

George Uhlenbeck had stressed the crucial importance of the thermodynamic limit; but on all these questions mathematical results of the necessary rigor were not readily forthcoming! In retrospect one can see that more was to be demanded in skill and effort than leaders in that generation had anticipated. For these reasons a number of us, perhaps most notably David Ruelle at the Institut des Hautes Études close to Paris in Bures-sur-Yvette, took up the challenge of bringing rigorous mathematics to bear on the fundamental problems of statistical mechanics.

And in 1965, on completing his studies in Physics at Rome and Florence, Giovanni Gallavotti joined enthusias-

tically in this task! For two years (1966-68) he worked at the IHES, where he met his first long-time collaborator, Salvador Miracle-Solé; and I soon heard of their joint work in Communications on Mathematical Physics establishing rigorous results for lattice systems and their correlation functions.

From France, Giovanni moved to the Rockefeller University; there in New York, probably at Joel Lebowitz's Yeshiva meetings, was where I first met him. And it was in this period, in collaboration with Douglas Abraham and A. Martin-Löf, that he initiated his renowned work on interfaces in Ising models, initially concerning the definitions of surface tension. But then, in 1972, Gallavotti proved rigorously that an interface in two dimensions of length L, rather than being straight, is subject to divergent transverse fluctuations of order . This striking result confirmed – for $d = 2$ – the predictions of the heuristic capillary wave theory advanced by Buff, Lovett and Stillinger (1965) that had been doubted by many serious researchers in the field.

On return to Rome which, apart from a year in Nijmegen and two in Naples, has been his firm base since 1970, Giovanni Gallavotti exhibited further his deep and powerful grasp of mathematics. Soon he made major contributions to the rigorous study of the renormalization group, introducing a tree expansion and a multiscale analysis of the underlying functional integral. Going beyond the tractable hierarchical models, he analyzed three- and four-dimensional systems and provided a rigorous theory of the removal of ultraviolet divergences in Euclidean field theory; his renormalization group methods were summarized in a milestone review in Rev. Mod. Phys. **57** (1985). Later, in the nineties with G . Benfatto, another long-time collaborator, he published fundamental work on the Fermi surface of quantal liquids including, notably, the Luttinger model.

From the early days Gallavotti has had a profound interest in nonequilibrium statistical mechanics. Indeed, in 1972 he wrote for his colleagues an "Internal Note of the Physics Department of the University of Rome" on the "Rigorous theory of the Boltzmann equation in the Lorenz model". Although never published, this has been called a stepping stone in the task of deriving rigorously a transport equation from basic Hamiltonian particle dynamics! Many of his subsequent contributions have addressed general properties of evolution: a comparison between billiards and Bernoulli schemes; the stability of motion near resonances in quasi-integrable Hamiltonian systems; the transition between ordered motion and chaos and the study of "twistless tori" arising in Kolmogorov-Arnold-Moser theory (where field-theoretic renormalization group techniques were brought to bear).

Of particular impact was Gallavotti's formulation with E.G.D. Cohen in 1995 of the "chaotic hypothesis" which provides a precise mathematical description for nonequilibrium stationary states. This led to work on relations to Onsager reciprocity and the fluctuation-dissipation theorem, applications to turbulence, extension of reciprocity to large fields, and the possibility of experimental tests.

Gallavotti's mathematics invariably reflects a deep physical understanding of the problems posed; consequently his work typically yields both physical and mathematical enlightenment. His teaching and more formal lectures have been widely and long appreciated while, over his four decades in research, he has had many international collaborators and coauthors. He is an author of ten textbooks, especially prized being his *Statistical Mechanics: A Short Treatise* (1999) and *The Elements of Mechanics* (1983); a second edition of his *Foundations of Fluid Mechanics* was published just two years ago.

Giovanni Galavotti has played his part in service to the community, on boards and through organizing meetings; personally, I especially appreciate his role in the excellent "Boltzmann's Legacy" Conference held last year in Vienna for the 100th anniversary of Boltzmann's tragic death. And in that year Giovanni also served as President of the International Association for Mathematical Physics.

Now let us hear from Giovanni Gallavotti himself: his theme is the transition from order to chaos and basic theorems that come into play.