ESI The Erwin Schrödinger International Institute for Mathematical Physics

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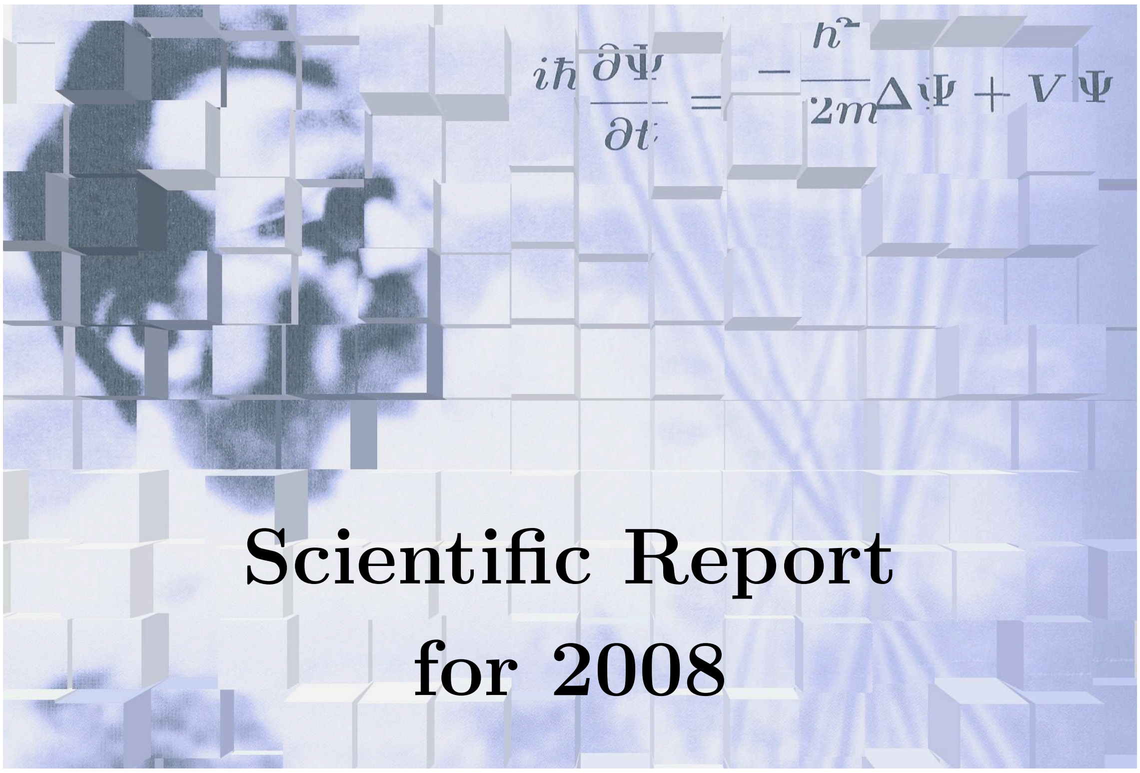

Scientific Report for 2008

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Preface

In 2008 the Erwin Schrödinger Institute turned fifteen: it celebrated its 15th anniversary on April 14, 2008, with a series of lectures by distinguished speakers on topics ranging from *Ultracold Atoms* (Rudolf Grimm, Innsbruck), *Supergravity* (Thibault Damour, IHES), *Quantum Ideas in Number Theory* (Don Zagier, MPIM and Collège de France), *Langlands Programme and Mirror Symmetry* (Ed Frenkel, Berkeley), to *Mathematical Biology* (Steve Evans, Berkeley).

The 15th anniversary the ESI was also an occasion for the Austrian Ministry of Science to evaluate the Institute's performance over the past 5 years and its scope for future development. The previous evaluation of the ESI by the Ministry in 2003 had been chaired by Nigel Hitchin (Oxford), who had recruited as co-evaluators Robbert Dijkgraaf (Amsterdam), Jürgen Jost (Leipzig), Nicolai Reshetikhin (Berkeley) and Vincent Rivasseau (Orsay). The evaluation in 2008 followed essentially the same pattern: Peter Goddard (IAS Princeton) agreed to chair the evaluation and chose for his panel of co-evaluators Jean-Michel Bismut (Orsay), Robbert Dijkgraaf (Amsterdam), Felix Otto (Bonn) and Scott Sheffield (Courant Institute). After a site visit by the panel in April 2008 the final report of the evaluation was sent to the Austrian Ministry of Science in June 2008.

In this report the review panel commented on the high quality of the programmes which had taken place at the ESI during the past five years and noted that the Institute had 'gently and wisely' increased its scope of the programmes in recent years, into areas of pure mathematics more remote at present from theoretical physics, and into areas of physics and biology beyond those usually characterized as mathematical physics. The panel felt that this process should be continued in the same judicious fashion as in recent years.

The report also contains a number of recommendations for the development of the ESI over the next years. These proposals and their financial implications are currently under further discussion with the University of Vienna and the Austrian Ministry of Science.

In terms of scientific activities, the year 2008 set a new record for the ESI. The Institute spent more than €810.000 on its scientific activities while keeping its infrastructure costs around €400.000 (as in previous years). The number of visiting scientists also set a new record: more than 700 mathematicians and physicists worked at the ESI in 2008. The following list should give an impression of the range of scientific activities of the Institute in 2008.

- Thematic Programmes:
  - *Combinatorics and Statistical Physics* (M. Drmota, C. Krattenthaler, B. Nienhuis, M. Bousquet-Mélou),
  - *Metastability and Rare Events in Complex Systems* (C. Dellago, P. Bolhuis, E. Vanden-Eijnden),
  - *Hyperbolic Dynamical Systems* (L.-S. Young, H. Posch, D. Szasz),
  - *Operator Algebras and Conformal Field Theory* (Y. Kawahigashi, R. Longo, K.-H. Rehren, J. Yngvason).
- In addition to these programmes a total of 11 workshops were organized at the ESI, including the following:

- *Tensor network methods and entanglement in quantum many-body systems* (F. Verstraete, G. Vidal, M. Wolf),
- *Frontiers in Mathematical Biology* (R. Bürger, J. Hermisson),
- *Combinatorics and Statistical Physics* (M. Drmota, C. Krattenthaler, B. Nienhuis, M. Bousquet-Mélou),
- *Topics in Mathematical Physics* (C. Hainzl, R. Seiringer, J. Yngvason),
- *Mathematical Challenges in String Phenomenology* (R. Blumenhagen, M. Douglas, M. Kreuzer, E. Scheidegger),
- *Structural Probability* (V. Kaimanovich, K. Schmidt)
- *Profinite Groups* (K. Auinger, F. Grunewald, W. Herfort, P.A. Zalesski).

Several of these workshops were specifically aimed at supporting the *ESI Junior Research Fellows Programme* mentioned below, and most of them were at least partially supported by external sources.

In its *Senior Research Fellows Programme* the ESI offered five lecture courses for graduate students and postdocs in 2008.

- *Introduction to Theoretical Soft Matter Physics* by Christos N. Likos (Universität Düsseldorf), October 2007 – January 2008,
- *Dualities between gauge theories and strings* by Radoslav Rashkov (Sofia University), October 2007 – January 2008,
- *Selected Topics in the Theory of Automorphic Forms for Reductive Groups* by Goran Muić (University of Zagreb), October 2008 – February 2009,
- *Operator algebras and conformal field theory* by Feng Xu (University of California, Riverside), November 2008,
- *Index theory, groupoids and noncommutative geometry* by Nigel Higson (Penn State University), November/December 2008.

The *ESI Junior Research Fellows Programme* had another very successful year. Under this programme 23 postdocs and PhD students worked at the ESI during 2008 and contributed significantly to the lively scientific atmosphere at the ESI.

Last, but not least in this account of scientific events and activities, I should mention the *ESI Lectures in Mathematics and Physics*, a lecture note series edited by the Institute's Scientific Directors Joachim Schwermer and Jakob Yngvason and published by the European Mathematical Society. Two further volumes appeared in 2008: *Boltzmann's Legacy* (edited by Giovanni Gallavotti, Wolfgang L. Reiter and Jakob Yngvason, 350 p.), and *Recent Developments in Pseudo-Riemannian Geometry* (edited by Dmitry V. Alekseevsky and Helga Baum, 549 p.).

The composition of the *International Scientific Advisory Committee* of the ESI saw a change in 2008: Giovanni Gallavotti (Roma) left the board in 2008 after 10 years of valuable service (his term would normally have ended in 2007, but he had kindly agreed to stay on the board for the 2008 Advisory Committee Meeting). John Cardy (Oxford) has joined the board with effect from 2008. I would like to give my sincere thanks to Giovanni Gallavotti for his many contributions to the ESI and to welcome warmly John Cardy to the board.

There was also a new arrival in the administration of the ESI in 2008. Irene Alozie had left the ESI office at the end of 2007, and in May 2008 the ESI was fortunate to fill the vacant position with Beatrix Wolf.

As in previous years I would like to thank the administrative staff — Isabella Miedl, Maria Windhager and Beatrix Wolf — for their friendly and efficient work and their unfailing good humour towards the visitors, research fellows and directors of the Institute.

Klaus Schmidt February, 2009
President

The ESI in 2008

Management of the Institute

Honorary President: Walter Thirring
President: Klaus Schmidt
Directors: Joachim Schwermer and Jakob Yngvason
Administration: Isabella Miedl, Maria Windhager, Beatrix Wolf
Computers: Andreas Čap, Gerald Teschl, Hermann Schichl

International Scientific Advisory Committee

John Cardy (Oxford)
Edward Frenkel (Berkeley)
Harald Grosse (Vienna)
Giovanni Gallavotti (Roma)
Nigel Hitchin (Oxford)
Gerhard Huisken (Potsdam)
Antti Kupiainen (Helsinki)
Michael Struwe (ETH Zürich)

Budget and visitors: In 2008 the support of ESI from the Austrian Federal Ministry of Science and Research was € 956.824,– (incl. € 100.000,– for the Senior Research Fellows Programme and € 166.824,– for the Junior Research Fellows Programme 2007) and € 29.000,– from the University of Vienna (incl. € 22.000,– for the Senior Research Fellows Programme). The total spening on scientific activities in the year was € 814.218,96 and on administration and infrastructure € 410.961,94.

The number of scientists visiting the Erwin Schrödinger Institute in 2008 was 734, and the number of preprints was 116.

Scientific Reports

Main Research Programmes

Combinatorics and Statistical Physics

Organizers: M. Bousquet-Mélou (Bordeaux), M. Drmota (Vienna), C. Krattenthaler (Vienna), B. Nienhuis (Amsterdam)

Dates: February 1 - June 15, 2008

Budget: ESI €73.532,92, FWF-Network "Analytic Combinatorics and Probabilistic Number Theory" €30.000,—

Preprints contributed: [2022], [2023], [2026], [2031], [2032], [2038], [2039], [2040], [2051], [2084], [2090], [2098], [2102], [2103]

Report on the programme

The special semester brought together around 70 researchers at the interface of the three broad areas of (1) *Enumerative Combinatorics*, (2) *Analytic Combinatorics* and (3) *Statistical Physics*. This included researchers from all generations, leading senior researchers as well as Ph.D. students and post-docs. The programme was a place of fruitful interaction between people with often very different background.

The main special event during the programme was a Workshop which took place May 18 – 31, and attracted about 45 participants, and during which 36 oral presentations were given, covering a wide range of topics.

Members of the combinatorics groups at the Fakultät für Mathematik of the Universität Wien and at the Institut für Diskrete Mathematik und Geometrie of the Technische Universität Wien used the opportunity to discuss and interact with the outside visitors of the programme amply, in particular also students and post-docs from these universities.

Even if it did not take place directly within the official period of the programme, a further major event organised within the programme was a Summer School on "Combinatorics and Statistical Physics", July 7 – 18, which was attended by about 35 young researchers at the Ph.D. or post-doc level. During this school, 4 lecture courses were given, by Philippe Di Francesco on *"Integrable Models of Statistical Physics and Enumerative Combinatorics,"* by John Imbrie on *"Combinatorial Aspects of Mayer Expansions, Forest Formulas, and Grassmann Integrals,"* by Christian Krattenthaler on *"Asymptotic Properties of Tilings,"* and by Thomas Prellberg on *"Combinatorial Enumeration with the Kernel Method."*

The Topics

The enumerative analysis of classes of combinatorial objects, in both the exact and the asymptotic sense, links the three subjects *"Enumerative Combinatorics," "Analytic Combinatorics,"* and *"Mathematical Statistical Physics."* The most classical is the first, which (mostly) deals with exact enumeration, the second develops the means to extract asymptotic information out of exact enumeration results, while the third examines (mostly) combinatorial models of physical phenomena, with the goal of analysing the behaviour of the models as their size goes to infinity, an analysis which is possibly based on an "exact solution" of the model. From this abridged description, it is obvious that the three subjects mutually overlap largely. The programme successfully stimulated exchange of ideas and collaboration between the researchers of these subjects. The main topics of the programme were:

- Integrability, q-Knizhnik–Zamolodchikov equation, 6-vertex model, alternating sign matrices, and plane partitions
- Asymptotic behaviour of the 6-vertex model
- Asymptotic analysis of dimer models
- Brownian motion
- Random graphs, random maps, random trees
- Percolation
- Random matrices and vicious walkers
- Cluster algebras and related combinatorics and physics

In the following paragraphs, brief summaries about the progress on these topics during the programme are provided.

Integrability, q-Knizhnik–Zamolodchikov equation, 6-vertex model, alternating sign matrices, and plane partitions

At the origin of this constantly expanding subject stands, on the combinatorial side, the problem of counting plane partitions and alternating sign matrices, and, on the statistical physics side, conjectures by Razumov and Stroganov, by Mitra, Nienhuis, de Gier and Batchelor, and by Zuber on ground state vectors of certain Hamiltonians in the dense $O(1)$ loop model, connecting them (conjecturally) to refined counting of fully packed loop configurations, which are just another disguise of 6-vertex model configurations (and alternating sign matrices). While the original conjectures are still wide open, it has become clear through ongoing work of Di Francesco, de Gier, Pyatov, Zinn–Justin (in various combinations) and co-authors, that the solution of the conjectures lies in the integrability of the models, and, more precisely, in special solutions of the q-Knizhnik–Zamolodchikov equation. Di Francesco and Zinn–Justin established sum rules for a large variety of loop models. Zinn–Justin was able to prove the Razumov–Stroganov conjecture for families of special components of the groundstate vector, and, as a by-product, settled (with Fonseca) the long-standing conjectures on the refined enumeration of totally symmetric self-complementary plane partitions. De Gier, Pyatov and Zinn–Justin have considered partial sum rules for the homogeneous limit of the solution of the q-deformed Knizhnik–Zamolodchikov equation with reflecting boundaries in the Dyck path representation. They showed that these partial sums arise in a solution of the discrete Hirota equation, and prove that they are the generating functions of τ^2-weighted punctured cyclically symmetric transpose complement plane partitions where $\tau = -(q+q^{-1})$. In the cases of no or minimal punctures, they prove that these generating functions coincide with τ^2-enumerations of vertically symmetric alternating sign matrices and modifications thereof. De Gier, Ponsaing and Shigechi worked out an explicit description of the finite size groundstate of the inhomogeneous transfer matrix of the $\mathrm{O}(n=1)$ loop model on a strip with non-trivial boundaries on both sides. Viennot presented an entirely new approach to fully packed loop configurations, using operators. This is inspired by an operator approach to the asymmetric exclusion process due to Derrida et al. It relates these to combinatorial objects (permutations tableaux and variations thereof), and thus has the potential of opening up unexpected links between these various objects.

Asymptotic analysis of the 6-vertex model and of dimer models

The asymptotic analysis of dimer models has made great progress recently, especially with the work of Kenyon, Okounkov, and Sheffield. This analysis concerns "typical" properties of random tilings of large planar graphs with given boundary conditions. In a (partially) parallel development, Ciucu has developed a program of showing that random tilings of large graphs exhibit features reminiscent of laws of electrostatics. This is done on the level of correlation functions of gaps in the region which is tiled. So far, the models analysed concerned regions without boundary or with a fixed boundary. During his 3-month visit at the ESI, Ciucu, jointly with Krattenthaler, considered for the first time an instance of a region with a free ('flexible") boundary. They were able to complete a precise exact *and* asymptotic analysis. Again, one can see electrostatic features, here, those resembling phenomena of electrostatics described by the method of images. A side result of this work is the discovery of intriguing factorisation properties of certain tiling generating functions, and of related classical group characters. While the 6-vertex model is not a dimer model, it is nevertheless very close. With the theorems of Kenyon, Okounkov and Sheffield on limit shapes of dimer models, a natural question to pose is whether there is also something like a "limit shape" for 6-vertex configurations. To begin with, one can ask this for alternating sign matrices (which are equivalent to 6-vertex configurations on a square grid with domain wall boundary conditions). Indeed, experiments indicate that there is such a limit shape. Colomo, in joint work with Pronko, addressed this problem by studying the emptiness formation probability (EFP) in the domain-wall six-vertex model. Assuming that the limit shape arises in correspondence to the 'condensation' of almost all solutions of the saddle-point equations for certain multiple integral representation for EFP, the limit shape of large alternating sign matrices is found. Paul Zinn–Justin observed that the Izergin–Korepin formula for the partition function of the 6-vertex model with domain wall boundary conditions can be re-expressed in terms of the partition function of a random matrix model with a non-polynomial interaction. Bleher used this observation to obtain the large N asymptotics of the free energy in the six-vertex model with domain wall boundary conditions. The solution is based on the Riemann–Hilbert approach. Bleher obtains the leading and subleading terms in the asymptotics of the partition function in the disordered and ferroelectric phases, and also on the critical line between these two phases.

Self-avoiding walkers and polygons

The enumerative analysis of self-avoiding walkers and polygons is a notorious problem in both statistical physics and combinatorics. The current state of affairs for the problem of asymptotic analysis is that the predictions of Nienhuis for the critical exponents would follow from work on stochastic Loewner evolution if one would establish the (conjectured) conformal invariance of the model. This still being open, Bousquet–Mélou and Guttmann have looked at special classes of self-avoiding walks and polygons, quasi-prudent and prudent self-avoiding walks and polygons. Even these are difficult to analyse. Guttmann undertook both exact enumeration and

Monte Carlo experiments, and showed that, for both models, it is likely that the exponent ν, characterising the growth of the mean-square radius of gyration through $\langle R_g^2 \rangle_N \sim \text{const.} \times N^{2\nu}$, is 1. Rechnitzer and van Rensburg introduced the concept of "atmospheres of self-avoiding walks" in order to estimate growth constants. They also extended this concept to self-avoiding polygons. Additionally, the new atmosphere statistics provide a way of significantly extending the applicability of the Rosenbluth method of approximate enumeration to previously inaccessible models such as self-avoiding polygons of fixed knot types.

Brownian motion, vicious walkers, and random matrices

During their stay at the ESI, Tóth and Vető considered different models of self-repelling random walks on the integer lattice $\mathbb{Z}$: the self-repulsion is defined in terms of the local time on the vertices, the unoriented or oriented edges. It turns out that the asymptotic scaling in the oriented edge case is different from the asymptotics of the other models. Tóth and Vető give the limit shape of the local time after long time and a limit theorem for the position of the random walker in different models. Systems of vicious walkers respectively, in the scaling limit, of non-colliding Brownian motions have been frequently considered in the literature recently. It is known that, if the initial configuration is in the eigenvalue distribution of GUE (respectively GOE) of random matrix theory, the non-colliding Brownian motions form a determinantal process (respectively Pfaffian process), in the sense that any multitime correlation function is given by a determinant (respectively Pfaffian) specified by a matrix-kernel. Katori, in joint work with Tanemura, used the integral representations for multiple Hermite polynomials studied by Bleher and Kuijlaars to show that the non-colliding Brownian motions with $N < \infty$ is a determinantal process for *any* initial configuration. A different point of view of vicious walkers (which are equivalent to rhombus tilings) was taken by Forrester. He considered a multi-component particle system underlying rhombus tilings of a half hexagon. In this particle system species j consists of $\lfloor j/2 \rfloor$ particles which are interlaced with neighbouring species. Forrester obtains the joint probability density function for this particle system, and shows in a suitable scaling limit that it coincides with the joint eigenvalue probability density function for the process formed by the successive minors of anti-symmetric GUE matrices. The correlations for this process are determinantal and an explicit formula for the corresponding correlation kernel can be given in terms of Hermite polynomials. Forrester computes as well scaling limits of the latter, giving rise to the Airy kernel, extended Airy kernel and bead kernel at the soft edge and in the bulk, as well as a new kernel at the hard edge.

Cluster algebras and related combinatorics and physics

Cluster algebras were introduced by Fomin and Zelevinsky as algebras unifying several well-known algebras that had occurred in a scattered way in the literature, and, in particular, in order to provide an algebraic framework for dual canonical bases and total positivity in semisimple groups. It has since been realised that they are related to many more mathematical subjects, originally not foreseen by Fomin and Zelevinsky. One of the (many) mysterious phenomena in connection with cluster algebras is the so-called "Laurent phenomenon." It refers to the fact (proved by Fomin and Zelevinsky) that, although cluster variables are computed using iterated application of substitution into a rational function, they turn out to be actually Laurent polynomials in the variables with which the process is started. In fact, something stronger seems to be the case, namely that the coefficients in these Laurent polynomials are in fact *non-negative* integers. Only very partial progress has been made so far. During their stay at the ESI, Di Francesco and Kedem gradually progressed on finite-type cluster algebras. They put together an impressive set of various tools, such as hard particle configurations, paths, heaps, non-intersecting lattice paths, refine these to, in the end, be able to settle the positivity conjecture for all finite-type cluster algebras of type A_r, which constitutes the first major result on the positivity conjecture.

Random Graphs, Random Maps, Random Trees

During the last few years there has been increasing interest in limiting objects of special classes of random graphs. We just mention the continuum random tree and the integrated superbrownian excursion that have been introduced by Aldous. Interestingly, these limiting objects do not only occur in the context of trees but also for other classes of random graphs like random triangulations and random quadrangulations. This problem was considered by Jean-François Marckert. Random triangulations and quadrangulations are special kinds of planar maps (that is, planar graphs together with a special embedding in the plane) and have a very rich combinatorial structure. In particular, the counting problem (which is related to the random setting) can be solved with the help of generating functions which was observed by Bouttier, Di Francesco and Guitter. This generating function approach (together with the Schaeffer bijection) allows one to study, for example, the distribution of the diameter of random quadrangulations (which is related to the support of the integrated superbrownian excursion). Bouttier, Di Francesco and Guitter presented significant extensions of their results. A different kind of limiting object for random graphs was presented by Janson, thereby extending results of Lovász and Szegedy. A closely related topic to random maps are random graphs, where one does not distinguish between different embeddings. Again a generating function approach (together with a delicate analytic treatment) can be used to characterise several limiting characteristics of these objects, including the vertex degree distribution (which is joint work of Drmota, Giménez and Noy). **Invited scientists:** George E. Andrews, Arvind Ayyer, Roger Behrend, Alexander Berkovich, Olivier Bernardi, Pavel Bleher, Jeremier Bouttier, Philippe Chassaing, Mihai Ciucu, Filippo Colomo, Sylvie Corteel, Jan de Gier, Deepak Dhar, Philippe Di Francesco, Michael Drmota, Jerome Dubail, Gerard Duchamp, Kari Eloranta, Omar Foda, Peter Forrester, Shmuel Friedland, Omer Gimenez, Evgeny Goryachko, Emmanuel Guitter, Tony Guttmann, Illes Horvath, John Imbrie, Masao Ishikawa, Jesper Lykke Jacobsen, Svante Janson, Jakob Jonsson, Makoto Katori, Rinat Kedem, Vladimir Korepin, Christian Krattenthaler, Yvan Le Borgne, Neal Madras, Jean-Francois Marckert, Anthony Mays, Marc Noy, Soichi Okada, Aleks Owczarek, Bernard Nienhuis, Vincent Pasquier, Boris Pittel, Anita Ponsaing, Thomas Prellberg, Pavel Pyatov, Balazs Rath, Alexander Razumov, Andrew Rechnitzer, Christoph Richard, Bruno Salvy, Keiichi Shigechi, Gordon Slade, Yuri Stroganov, Balint Toth, Remco van der Hofstad, Buks Janse van Rensburg, Anatoly Vershik, Xavier Viennot, Yuri Yakubovich, Jiang Zeng, Yao-Zhong Zhang, Paul Zinn-Justin

Metastability and Rare Events in Complex Systems

Organizers: P. Bolhuis (Amsterdam), C. Dellago (Vienna), E. van den Eijnden (New York)

Dates: February 1 - April 30, 2008

Budget: ESI €48.160,88, ESF-Network SimbioMa €5.000, COST-Network MolSimu €4.000

Report on the programme

Many processes occurring in nature and technology such as the folding of a protein or the transport of a dopant through a semiconductor are characterized by the presence of a wide range of different time scales, complicating the study of such processes with computer simulations. Often such wide ranges of time scales are due to energy barriers or entropic bottlenecks that hinder the motion of the system and partition phase space into metastable basins. Transitions between basins are rare but proceed rapidly if they occur. Naturally, such rare but important events create complications for molecular dynamics simulations since the need to faithfully reproduce both short and long time scales causes excessively long simulation times. In the last few years, the investigation of rare events in physics, chemistry and biology by computer simulation studies has made tremendous progress. One of the main goals of this workshop was to discuss novel ideas, methods and approaches to investigate the properties of rare event processes and to bring together people working on rare events in a wide range of fields ranging from physics and chemistry to materials science and molecular biology. In particular, the hope was to establish closer links between people engaged in methods development and participants working on their application to large scale systems. In the following we report briefly on the organization of the ESI-program and then briefly survey the main scientific questions discussed during the program.

As customary at the ESI, the programme was organized loosely during most of the time to promote free wheeling discussions and collaborations between the participants. This format is made possible by the excellent working conditions provided by the ESI to all participants during their stay including the possibility for individual work in separate offices and for group discussions in the common room, the seminar rooms and, especially, the hall ways. The three-month period was punctuated by two workshops with formal talks and poster presentations. The first, and larger of the two workshops, ran for a week, February 18-22, and covered all the topics of the workshop. During the week before the formal workshop, several participants gave longer talks that were thought as introductory lectures to some of the central topics of the programme. The second, and more specialized workshop was focused on the theoretical and computational description of nucleation processes in condensed matter systems and ran for two days, April 16-17. All participants contributed to the workshops either in form of formal presentations or in informal discussions. The workshops were financially supported with additional funds obtained from the ESF-network SimBioMa and the COST-Action P13 MolSimu.

It is worth noting that the average age of the speakers was low compared to other meetings of this sort. All workshop participants were offered to bring along students and young collaborators such that they could get in touch with the international community, and many colleagues made use of this possibility. Scientifically, the main questions discussed in the whole program, and with particular intensity during the two workshops, were:

- How can one identify metastable sets? Many techniques presuppose that these are known, at least roughly. Is this sufficient in applications, i.e. are the results of the techniques above robust against slight variations of the boundary of these sets? Or does one have to do better than this, using, e.g., clustering techniques that identify metastable sets from scratch, at least in principle.

- What is the best reaction coordinate? There is now a growing consensus that this should be the committor, or isoprobability surfaces which are defined such that a trajectory initiated on these surfaces has a uniform probability on the surface to reach one metastable set rather than the other. How to identify these surfaces?

- Does one have to compute transition trajectories first, then reconstruct the surfaces from these data, or can one bypass this calculation and identify the isoprobability surfaces directly? The free energy with the right dynamical content is the one associated with the isoprobability surface. But how can one compute this free energy efficiently given this reaction coordinate? What is the relation between free energy and reaction rate?

- The free energy with the right dynamical content is the one associated with the isoprobability surface. But how can one compute this free energy efficiently given this reaction coordinate? What is the relation between free energy and reaction rate? Does one really have to run dynamical trajectories, e.g., as in the Bennett-Chandler procedure to compute the reaction rate, or can one deduce it directly from the free energy?

- Given the isoprobability surfaces, how can one understand their physical meaning, i.e. how can one describe the mechanism of the reaction from the knowledge of these surfaces. The isoprobability surfaces have just one dimension less than the original space, so it is far from obvious how to analyze their content.

- How should we model nucleation processes? How important is the dynamical nature of the model? How important are kinetic effects for nucleation?

- Are there possibly multiple routes in nucleation? And how does one deal with pre-ordering in nucleation of mixtures? What are the pathways available to the system if there are several metastable phases nearby? Is Ostwald's step rule always obeyed? How does anisotropy in growth or in shape, influence the nucleation process? How does nucleation occur in finite small systems and in confined geometries?

In the following we will give an overview of the talks and discussions that have addressed these questions during the meeting. For better clarity we have organized our report in six categories.

1. Sampling rare transition pathways: mechanism and kinetics

Several approaches to find rare transition trajectories in complex systems and compute the corresponding rates have been the focus of many discussions and talks. *Jorge Kurchan* described a novel and efficient method to find trajectories with atypical stability properties of a dynamical system. This method can be used to find reaction currents between metastable states, to find soliton and breather modes and to detect stability islands in chaotic systems. *Michael Grünwald* presented a way to improve the transition path sampling shooting move for long, flat free energy barriers. The efficiency of this move is hampered by the finite precision of computer floating-point numbers. Grünwald solved this problem by realizing that the linear short-term behavior of small disturbances in phase space enables arbitrarily small disturbances in the shooting move. *Jutta Rogal* reported on her recent work on multi-state transition path sampling for systems with metastable intermediates. *Titus van Erp* presented a novel combination of the transition interface sampling method (which is based on the transition path sampling) with replica exchange to study multiple rare event reaction pathways. He also discussed why the path sampling rate constant computation is less sensitive to the choice of reaction coordinate than other biased sampling methods. *Ron Elber* presented the Milestoning algorithm to compute the time evolution of the system undergoing a rare event even if the process is not activated and does not follow Poisson statistics. Milestoning is based on the local first passage time distributions between hypersurfaces (LFPTD) in phase space called milestones. Elber showed with an application to the myosin protein that the method describes the timescales and free energy surface well. *Tommy Miller* addressed the problem of sampling diffusive transition paths with the goal of simulating soft matter dynamics on long timescales, by expressing the path distribution as a convenient path weight functional using the Onsager-Machlup action. Recently developed path integral Monte Carlo techniques can be employed to sample different segments of the transition paths in parallel in a low-communication scheme. *Dirk Zahn* discussed transition path sampling approaches to study nucleation mechanisms, coalescence/competition of multiple nuclei during phase growth, and the interplay of separation processes with nucleation and growth. Some limitations of transition path sampling were illustrated with the example of crystal nucleation from solution. *Tom Woolf* reviewed the dynamic importance sampling method applied to biomolecules and discussed how computed kinetic pathways can be tested and used within an experimental setting. *Aaron Dinner* discussed the problem of finding good reaction coordinates and presented his methods for an automated analysis of path sampling simulations. His application of this method to a DNA repair protein revealed a two-step nucleotide-flipping mechanism.

Besides obtaining the ensemble of trajectories it is often essential to analyze the path ensemble to gain understanding of the essential reaction coordinate of the process. *Baron Peters* introduced the likelihood maximization approach for obtaining accurate reaction coordinates using the "Aimless Shooting" version of transition path sampling. This method also allows a quantitative extension of committor probability analysis for assessing reaction coordinate accuracy. He illustrated the method on a barrier crossing in a model free energy landscape, nucleation in the Ising model, and nucleation of a polymorph transformation in terephthalic acid crystals. *Maddalena Venturoli* studied the kinetics of phase transitions in the two dimensional Ising model under different conditions using the string method, which computes the minimum free energy path (MFEP) in a collective variables space. The proposed collective variables consisting of block of spins were shown to explain the mechanism of the phase transformation.

2. Out of equilibrium pathways

In non-equilibrium situations most of the equilibrium methods are not applicable, because of the presupposed knowledge of the stationary distribution which is usually unknown away from equilibrium. *Rosalind Allen* presented an application of the forward flux sampling method (FFS) to nucleation in an Ising model. FFS has gained much attention in the community due to its simplicity and versatility, for example in non-equilibrium system. Allen discussed the effect of shear on the nucleation process, something that was previously not possible. *Chantal Valeriani* reported on a numerical study of the rate of crystal nucleation in a binary suspension of oppositely charged colloids using the FFS method. The crystal phase that nucleates was found metastable and, more surprisingly, its nucleation free energy barrier was not the lowest one in direct contradiction with the common assumption that the nucleating phase is the one with the lowest free-energy barrier.

David Chandler discussed the use of sampling of trajectory space for studying non-equilibrium systems such as a glass transition. He introduced a statistical mechanics formalism of space-time and its associate thermodynamics. This enables one to treat non-equilibrium transitions in a systematic and rigorous way. *Aaron Dinner* presented a novel way to extend the use of umbrella sampling (biased sampling) to the exploration of non-equilibrium processes that do not obey detailed balance. He described how to enforce equal sampling of different regions of phase space in an ergodic system arbitrarily far from equilibrium while still being able to determine the corresponding steady-state probability distribution with high accuracy. *Paul Maragakis* introduced a new differential non-equilibrium thermodynamics identity based on the Crooks fluctuation theorem. Several existing non-equilibrium thermodynamic identities followed directly from this differential fluctuation theorem. He demonstrated the theorem on the analysis of molecular dynamics simulations of alanine dipeptide conformational change, and argued that it could be used to analyze laboratory experiments as well.

3. Free energy landscape exploration

While computation of free energies has been important since the dawn of computer simulation, the exploration of free energy landscapes in large complex systems such as biomolecular isomerization has only recently become possible. The field of free energy exploration has gained a lot of momentum with the invention of metadynamics in 2002. The method is based on the notion of adding a bias potential to the potential energy, and is very efficient because the bias is altered on the fly during the simulation. In this sense it is reminiscent of the Wang-Landau algorithm for obtaining density-of-states.

In recent years there have been many improvements on the metadynamics methodology. Several speakers presented this progress in this workshop. *Giovanni Bussi* discussed a recently developed formalism that provides a unified description of Metadynamics and the canonical NVT sampling. The advantage of this formalism is that convergence and errors can be rigorously and easily controlled. The parameters of the simulation can be tuned to focus the computational effort only on the physically relevant regions of the order parameter space, enhancing the efficiency. *Francesco Gervasio* presented an application of the combination of metadynamics using path variables and parallel tempering (aka as replica exchange). He showed that this greatly enhances performance of the sampling of configuration space and allows the finding of reactive pathways in complex systems. The application on folding of β-hairpin illustrated the methods. *Alessandro Laio* presented an application of the combination of replica exchange and metadynamics to protein folding. He predicted the influence of mutations on the native state stability, which was validated by experiment. *Bernd Ensing* presented a novel algorithm based on combining ideas from the string method and metadynamics in order to find efficiently the lowest free energy pathway in a space of collective variables. This approach effectively enables to extend the metadynamics method to more than 3 dimensions.

Another topic of interest is the search for global free energy minima in high dimensional systems. Straightforward minimization based on importance sampling or dynamics is not possible because of the size of phase space, and because of the high free energy barriers between the free energy minima. However, the use of non-physical moves has helped in the past tremendously to find optimized structures. One possibility is to employ such non-physical moves in evolutionary or genetic algorithms. *Artem Oganov* discussed such an algorithm that allowed prediction of the crystal structures based just on the chemical formula. The method involves an evolutionary algorithm that explores the phase space and finds global minima very effectively. Oganov discussed the importance of the methods key ingredients: selection, variation operators, and redundancy control. The method was illustrated by predicting the high-pressure phases of hydrogen, oxygen, and boron.

All these contributions show that the exploration of free energy landscape has become much more efficient in recent years, due to the development of novel methods. This workshop has helped to understand the pros and cons of these methods, and has given ideas for future work.

4. Computation of free energies

Instead of exploring rough energy landscapes one might also be interested in the free energy differences between two different states. Although there are many approaches available, an accurate but efficient estimate of free energies differences in complex systems is still a challenge. *Manuel Athenes* presented a new method that uses path sampling to compute free energy differences between two different states in complex systems. He also presented a recent extension that enabled the computation of the statistical entropy of systems driven out of equilibrium. *Ricardo Chelli* presented an approach to estimate the potential of mean force along a generic reaction coordinate based on maximum likelihood methods and path-ensemble averages in systems driven far from equilibrium. The method applied to the unfolding process of the alpha-helix form of an alanine deca-peptide, gave results in good agreement with thermodynamic integration. These contributions indicated that much progress is being made in this area. *Luca Maragliano* proposed a simple, efficient and accurate method to map multi-dimensional free energy landscapes. The method employs temperature-accelerated molecular dynamics to rapidly sweep through the important regions of the free energy landscape and compute the gradient of the free energy locally, together with a variational method using radial-basis functions to reconstruct the free energy globally from this local gradient. Maragliano illustrated the method on numerical and molecular dynamics examples. *Tanja Schilling* reported on the free energetics of depletion induced percolation- and phase-transitions.

5. Master equation methods

In complex molecular systems with many degrees of freedom it is often very difficult to determine whether the dynamics can be viewed as a sequence of hops between long-lived metastable states. The main difficulty here consists in identifying such stable states and describe their basins of attraction. Several methods that address this issue were considered during the program. *John Chodera* presented an approach based on coarse-graining statistical dynamics of complex processes such as biomolecular conformations into discrete-state, continuous-time master equation models. He explained how by using all-atom molecular dynamics simulations in explicit solvent one can determine the range of timescales over which the models faithfully describe dynamics, assess the uncertainties in computed properties, and extract insight about long-timescale processes. *Gerhard Hummer* presented how to employ coarse master equations and diffusion models to study the equilibrium and non-equilibrium properties of molecular systems. These models are constructed using maximum likelihood and Bayesian approaches from the observed dynamics. The use of a Green's-function based formalism circumvents issues arising from fast non-Markovian dynamics. The general formalism for the construction of coarse master equations was illustrated with several examples ranging from molecular fluids to protein folding. *Christof Schütte* presented a novel approach to the identification of metastable states like biomolecular conformations via the optimal statistical representations of transition kernels of the underlying dynamics. Compared to other approaches this approach scales favorably with the size of the system and allows deriving some of the alternative approaches from some fundamental principles.

To assess long time kinetics of a complex system, the kinetic Monte Carlo (KMC) method can be very powerful. Several speakers focused on the use of KMC for coarse-graining dynamics. *Karsten Reuter* discussed how to coarse grain rare surface chemical reactions from the electronic structure level to very long time scales, using density-functional theory, kinetic Monte Carlo and rate equation theory. *Normand Mousseau* presented a novel dynamical activation-relaxation technique that combines the activation-relaxation technique with a non-lattice kinetic Monte Carlo method that allows on-the-fly identification of barriers and full treatment of lattice deformations. A topological description of the system structure at each moment allows the method to identify rapidly these new environments and to move forward efficiently.

Rodolphe Vuilleumier presented a way to directly calculate the microscopic velocity field around a diffusing particle using numerical simulations to bridge the gap between the atomic model and the hydrodynamics approach. The hydrodynamics flow is recovered beyond a few atomic radii from the tagged particle. However, there was a finite normal velocity at the boundary, which seemed in contradiction with the non-penetrability of the particles but turned out an effect of fluctuations. This led to the conclusion that the flux of momentum in the flow is not determined solely by viscosity but also from the diffusion of the tagged particle, giving new insight in the diffusion process in liquids and in particular on the role of fluctuations at the atomic level.

6. Nucleation processes

At the workshop on nucleation processes, on the first day the talks of two of the major figures in the field, *Kurt Binder* and *Daan Frenkel*, sparked an intense discussion that filled the rest of the day. The main subject of this discussion was whether the so-called committor function provides a useful way to describe the nucleation process. Kurt Binder emphasized the importance of making contact with the experiments and questioned the general usefulness of the committor function based on the extensiveness of the nucleation rate measured in experiments. The committor provides a meaningful way to characterize the nucleation process only if the growth of a single nucleus is considered. The contributions of Paul Wagner, who emphasized the viewpoint of the experimentalist, proved particularly useful in putting the theoretical methods and questions into perspective.

The second day of the workshop started with short talks by *Richard Sear*, *Marjolein Dijkstra*, *Peter Bolhuis*, *Michael Grünwald*, *Pep Espanol*, and *Chantal Valeriani*. These talks were followed by detailed discussions particularly about the reaction coordinate of various nucleation processes. Overall, all participants considered the workshop to have been very useful and stimulating. The organizers of this workshop are planning to submit a proposal for a workshop at CECAM, the Centre Europen de Calcul Atomique et Molculaire in Lausanne, Switzerland, and all participants of the Vienna workshop have expressed their enthusiasm and their willingness to continue the discussions started at the ESI.

Overall, the ESI-program on Metastability and Rare Events in Complex Systems can be considered a success as demonstrated by several new collaborations initiated during the meeting. After the event, a number of participants have suggested that follow-up meetings organized in, say, two-year intervals might help to keep the momentum the community has demonstrated during the workshop.

Invited Scientists: Rosalind Allen, Manuel Athenes, Alessandro Barducci, Gerard Ben Arous, Kurt Binder, Peter G. Bolhuis, Sara Bonella, Georgios Boulougouris, Tomas Bucko, Giovanni Bussi, David Chandler, Riccardo Chelli, John Chodera, Giovanni Ciccotti, Grazia Cottone, Christoph Dellago, Luigi Delle Site, Aaron Dinner, Christof Drechsel-Grau, Ron Elber, Yael Elmatad, Bernd Ensing, Mauro Ferrario, Kristen Fichthorn, Francesco Gervasio, Arseni Goussev, Michael Grünwald, Carsten Hartmann, Martin Held, Gerhard Hummer, Jorge Kurchan, Alessandro Laio, Zbigniew Lodziana, Peter Majek, Paul Maragakis, Luca Maragliano, Simone Marsili, Philipp Metzner, Thomas Miller, Normand Mousseau, Dorota Niezialek, Frank Noe, Emad Noorizadeh, Artem Oganov, Baron Peters, Matej Praprotnik, Piero Procacci, Karsten Reuter, Jutta Rogal, Tanja Schilling, Christof Schütte,Titus van Erp, Koos van Meel, Chantal Valeriani, Eric van den Eijnden, Maddalena Venturoli, Rodolphe Vuilleumier, Art Voter, Jonathan Weare, Jan Wigger, Steve Wiggins, Adam Willard, Tom Woolf, Dirk Zahn

Hyperbolic Dynamical Systems

Organizers: H. Posch (Vienna), D. Szász (Budapest), L.-S. Young (New York)

Dates: May 25 - July 5, 2008

Budget: ESI €83.319,22

Preprints contributed: [2022], [2067], [2070], [2071], [2074], [2075], [2076],[2077], [2078], [2084], [2086]

Report on the programme

In 1996, Philippe Choquard, Carlangelo Liverani, Harald Posch and Domokos Szász organized the semester *Hyperbolic Systems with Singularities* at the ESI. The name of the semester was chosen to indicate that the organizers intended to go beyond billiard like systems, to understand them as solely - though quite important - examples of hyperbolic systems with singularities. The hope was that the wider framework will help science to better understand billiard like systems. It is worth pointing out here one of the many important results of this 1996 ESI semester: Lai-Sang Young's tower construction. (Her paper appeared in 1998 in Annals of Mathematics and is an ESI preprint No. 445). Probably the most sensational result of that paper was that exponential decay of correlations for planar finite horizon Sinai billiards was proven exactly by using the advantage of considering billiards from this broader perspective, namely as hyperbolic systems with singularities. In this way, part of her tools and ideas were borrowed from methods worked out for the Hénon map, for unimodal maps of the interval, etc. In a rough sense, the central idea of Young's 1998 paper is a new kind of symbolic representation – the tower construction – that has turned out to be flexible and powerful enough to investigate various statistical properties for a wide scale of hyperbolic systems. Since then billiard methods are getting better and better embedded into the theory of hyperbolic dynamical systems.

The name of the 2008 semester was not novel: *Hyperbolic Dynamical Systems*, and the organizers were Harald Posch, Lai-Sang Young and Domokos Szász (thanks are also due to P. Bálint and I. P. Tóth, who helped with the organization of the program). The fact that physicists have been among the organizers (Harald Posch both times and Philippe Choquard in 1996) reflects the fact that the topic is central to both mathematics and physics. Furthermore the composition of a mixed audience has the absolute advantage that both mathematical and physical theories can gain a lot form the interaction of the communities involved.

Since 1996, there have been many important developments in the field. On the one hand, new approaches appeared for studying statistical properties of hyperbolic dynamical systems. Common feature of these methods is that instead of coding the system and proving theorems in a symbolic setting, the dynamics are investigated directly on the phase space. On the other hand, in addition to studying individual dynamical systems, new perspectives opened up for understanding how the long term behavior is effected when the parameters of the dynamics change. This in turn provides new tools for studying spatially extended and non-equilibrium phenomena, both very interesting for physics applications. Of course, the above two types of developments are strongly interrelated.

The aim of the semester was to give an overview of the current status of research in these directions, and to provide a forum for interactions that may result in fruitful collaborations. Before going into the details, let us describe first the structure of the semester.

Structure of the semester

The time span was rather short: six weeks altogether. Using the abbreviation Wn for the n-th week, n=1, 2, ..., 6, W2 - W5 were the central parts of the program.

- During W2 and W5 two workshops were organized. W2 (June 2-6) focused on nonequilibrium systems and was organized essentially by Harald Posch with the assistance of the coorganizers. The W2 workshop had a rich and dense program, with altogether 22 one-hour talks.
- W3 and W4 had a special structure. During each of them 3 minicourses were held, each consisting of three one hour lectures. Thus there were 6 minicourses altogether, which presented different approaches to studying ergodic and statistical properties in hyperbolic dynamical systems, and applying such techniques to problems arising from physically relevant questions. In addition to the minicourses, we also had a limited number of seminar (60 min) and report talks (30 min) on W3 and W4.
- The W5 workshop concentrated on various aspects of hyperbolic dynamics and its applications to physics. The programme was again quite rich and dense, in addition to 13 longer (50 min) and 7 shorter (30 min) talks, there were also three mini-series, each consisting of two one hour lecture.
- During W1 and W6 we had a fewer number of participants, and correspondingly, a fewer number of lectures. This more relaxed program provided in turn excellent conditions for discussions and collaborations.

Details: topics, workshops and minicourses

As the programme for the different weeks was strongly connected, instead of chronological listing, it seems more reasonable to report on the progress made thematically for the semester as a whole.

W2 was somewhat exceptional, as its main focus was on non-equilibrium phenomena and not on hyperbolic dynamics. For this reason we first summarize the program of W2.

The list of the speakers in focus week W2 is impressive: Benettin, Eckmann, Gaspard, Jacquet, Jona-Lasinio, Mukamel, Pillet, Politi, Presutti, Rey-Bellet, Rondoni, Ruelle, Sanders, Schlein, Vulpiani, Young. Extended (two hours) introductory lectures were given by Ruelle on *Nonequilibrium statistical mechanics and smooth dynamical systems*, by Presutti on *Persistence of randomness in macroscopic limits*, and by Pillet on *C^*-dynamical systems and nonequilibrium quantum statistical mechanics*. They proved to be extremely useful for the general talks and discussions, which concentrated on four major topics:
a) Hamiltonian systems: low-dimensional particle systems
b) Hamiltonian systems: anharmonic chains and coupled maps
c) Stochastic systems
d) Open quantum systems
In the last decade these problems have been in the focus of attention of both mathematicians and physicists. We mention some of the fundamental problems discussed at the focus week:

- One problem, to which the community of mathematical physicists has been returning regularly is Fourier's law of heat conduction: What is the minimum set of assumptions required for the Fourier law to hold, and how can the theory be extended to more and more realistic physical systems from purely microscopic, Newtonian assumptions on the dynamics? Eckmann considered a one-dimensional deterministic particle model for heat conduction, consisting of a chain of cells with scatterers, around which other point particles move. In the continuum limit a Boltzmann equation is derived, which is proved to have a unique non-equilibrium stationary solution for stochastic driving forces at the boundary. Taking a two-dimensional Billiard model without mass transport as an example, Gaspard discussed the first-principles derivation of Fourier's law for a case, for which i) the short time scales for establishing local thermal equilibrium, ii) the intermediate scales for local thermalization, and iii) the macroscopic time scales for the relaxation of the Fourier modes are well separated. Anomalous heat conduction in one- and two-dimensional dynamical and stochastic models were discussed by Politi and Benettin. It is fair to say that the present understanding of heat conduction in general, and of the derivation of Fourier's law from first principles in particular, has been significantly improved since the ESI semester in 1996.

- Another topic of significant importance are large fluctuations and limit theorems for equilibrium and out-of-equilibrium systems. For example, the famous fluctuation theorem for the entropy production in Anosov-like stationary nonequilibrium systems (Gallavotti, Cohen) is one of the few exact results available for systems far from equilibrium. Using the Young tower construction, Rey-Bellet presented large deviation principles for various classes of dynamical systems, which include dispersing billiards and strange attractors of rank one such as the Hénon attractor.

- Diffusion is another transport process which surfaced in various presentations in W2. Jona-Lasinio presented a self-contained, purely macroscopic field theory of diffusion with and without the action of external fields. No reference to the underlying microscopic dynamics is made. The approach allows the computation of correlation functions from a free energy functional, which turns out to be non-local. As expected, correlations over macroscopic scales develop for non-equilibrium states. Another aspect of diffusion was discussed by Rondoni, namely the onset of diffusive behaviour of finite-sized particles in models for microporous membranes. It is found that inter-particle interactions are much more important for the transition to diffusive behavior than even defocusing particle-wall collisions. The former are not bound to occur at fixed positions and break correlations more efficiently.

- Driven one-dimensional lattice models are an extremely useful tool to study the phase separation and ordering in non-equilibrium states. Such studies are of eminent practical interest, as the daily traffic jams on our roads demonstrate. The conditions for phase separation for various models with probabilistic site dynamics were discussed by Mukamel and Sanders. Phase diagrams and system-size scaling were studied.

- Quantum mechanical aspects of non-equlibrium transport were discussed by Schlein, who concentrated on the dynamics of Bose-Einstein condensates, once the confining magnetic field is switched off. Jacquet provided a quantum version of the classical one-dimensional Eckmann-Young model for mass and heat conduction. He computed the average electric and heat currents along a chain of quantum dots in the linear response regime. It turns out that these currents are typically governed by Ohm and Fourier laws.

In conclusion it can be said that week W2 provided high-level discussion on many of the most important problems of non-equilibrium statistical mechanics, both classical and quantum mechanical. The extended introductory lectures helped to establish a rather coherent view of the field.

Now let us turn back to the description of the program for the rest of the weeks. Most of the activity focused on understanding statistical behavior in hyperbolic systems and its applications to modeling physics phenomena. This issue has many different aspects, most of which was strongly represented at the semester. Here we only have a chance to describe some of the main directions, the topics to which several of the participants contributed. It is beyond the scope of this report to describe all the activity, and some very significant directions are not even mentioned. On further details (eg. detailed program, abstracts of talks, lecture notes) please consult the homepage of the semester available at:

`http://www.math.bme.hu/~walzer`

- *Applications of the tower method and of inducing schemes in general*: as mentioned above, an approach that proved to be very successful in understanding statistical properties of hyperbolic dynamical systems is to use some kind of symbolic representation, in particular the tower constructions initiated by Young. Bálint and Tóth studied in this setting the issue of correlation decay in multidimensional dispersing billiards (W3 minicourse). Recently Young towers have been applied to study further statistical properties such as large deviations – Melbourne (W5), Rey-Bellet (W2) – and extreme value distributions – Török (W5). The general approach of inducing schemes, which is strongly connected to tower constructions, was the central tool in several other lectures – eg. Pesin (W2), Luzzato (W2), Alves (W5).

- *Banach space techniques*: An idea that is recently being applied more and more successfully in the ergodic theory of hyperbolic systems is to consider a carefully chosen generalized function space of observables defined directly on the phase space, and to investigate the spectrum of the transfer operator of the dynamics in this setting. Progress made in this direction was reported by the W4 minicourses of Baladi (W4) – with an emphasis on hyperbolic systems with singularities; and Liverani – pointing out applications to spatially extended systems in particular. It is definitely worth mentioning that the method has been recently successfully applied to hyperbolic flows – cf. in particular Tsujii (W5).

- *Coupling techniques*: Another way of studying hyperbolic dynamics without coding the system is to identify a suitable class of measures (roughly speaking, densities supported on unstable manifolds) and to investigate, by implementing coupling ideas of probability theory, how the elements of this class get equidistributed as time evolves. The W3 minicourse by Chernov described this approach in detail, while other talks reported on applications to spatially extended problems – eg. Dolgopyat (W3 minicourse), Varjú (W5).

- *Averaging and its applications*: Averaging naturally appears in the physical context of separation of time scales. It is investigated whether the evolution of certain slow variables can be understood as if another class of variables, the fast ones, acted as a statistically averaged background. The issue is, on the one hand, strongly related to spatially extended dynamics, and, on the other hand, to the robustness of statistical properties with respect to perturbations. The W3 minicourse by Dolgopyat analyzed how averaging appears when applying martingale techniques to prove that diffusion type behavior arises in deterministic systems. Further aspects of averaging were discussed in many other talks, eg. Kifer (W3), de Simoi (W4), Wright (W4).

- *Coupled map lattices* are probably the most popular and best understood examples of spatially extended dynamics. On the one hand, in the context of Banach space techniques (see above) there has been important progress in the problem of proving uniqueness and existence of the invariant measure in the small coupling limit; as discussed eg. in the W4 minicourse by Liverani. On the other hand, new perspectives opened up for handling the issue of phase transitions in a mathematically rigorous way; such developments, in the case of mean field coupling, were presented in the W5 miniseries by Keller .

- *Open systems* are of increasing interest for both the mathematics and the physics community. Thanks to the technical developments mentioned above, now there are better chances for understanding conditionally invariant measures – cf. the talks of Bunimovich (W5) and Demers (W5).

Let us finally mention some further topics which, even though less directly connected to statistical properties of hyperbolic dynamical systems, were in the focus of the semester. Their appearance indicates the interdisciplinary character of the programme, and the fact that the theory of hyperbolic systems has important messages for lots of areas of mathematics and physics in general, and of dynamical phenomena in particular.

- In one of the W5 miniseries Marklof reported on very remarkable recent results concerning the *Boltzmann-Grad limit of the periodic Lorentz gas.* This topic has important connections to various areas of number theory and mathematical physics. Talks on related results were given by Khanin (W1) and Bachurin (W5).

- *Hyperbolic phenomena in the vicinity of homoclinic bifurcations.* Talks by Kaloshin (W4), and Gorodetski (W5, W6) presented important progress in this field which have implications, in particular, for better understanding systems like the three body problem or the standard map.

- *Well-posedness and singularity in hydrodynamics.* In a W5 miniseries Li explained his recent results, joint with Sinai, on constructing singularities in the three dimensional complex valued Navier-Stokes system.

- A W4 minicourse by Wilkinson was devoted to her latest results on the ergodic theory of *partially hyperbolic systems*, an issue that has again important connections to the main questions of the semester, both at the phenomenological and at the technical level.

Invited scientists: Jose F. Alves, Pavel Bachurin, Viviane Baladi, Peter Balint, Felipe Barra, Giancarlo Benettin, Nils Berglund, Frederico Bonetto, Leonid Bunimovich, Alexander Bufetov, Francesco Cellarosi, Nikolai Chernov, Pierre Collet, Gianluigi del Magno, Mark Demers, Jacopo de Simoi, Dmitry Dolgopyat, Jean-Pierre Eckmann, Pierre Gaspard, Guido Gentile, Thomas Gilbert, Paolo Giulietti, Anton Gorodetski, Sebastian Gouezel, Alexander Grigo, Nicolai Haydn, Phil Howard, Huy Hu, Philippe Jacquet, Gianni Jona-Lasinio, Vadim Kaloshin, Gerhard Keller, Konstantin Khanin, Yuri Kifer, Rainer Klages, Antti Kupiainen, Oscar Lanford, Francois Ledrappier, Marco Lenci, Dong Li, Kevin Lin, Carlangelo Liverani, Stefano Luzzatto, Roberto Markarian, Jens Marklof, Ian Melbourne, Eugen Mihailescu, David Mukamel, Peter Nandori, Wiliam Ott, Zsolt Pajor-Gyulai, Francoise Pene, Yakov Pesin, Claude-Alain Pillet, Antonio Politi, Mark Pollicott, Harald Posch, Errico Presutti, Luc Rey-Bellet, Lamberto Rondoni, David Ruelle, David Sanders, Benjamin Schlein, Nandor Simanyi, Mikko Stenlund, Luchezar Stoyanov, Domokos Szasz, Andrew S. Torok, Imre Peter Toth, Masato Tsujii, Henk van Beijeren, Tamas Varju, Angelo Vulpiani, Amie Wilkinson, Maciej Wojtkowski, Paul Wright, Tanya Yarmola, Lai-Sang Young

Operator Algebras and Conformal Field Theory

Organizers: Y. Kawahigashi (Tokyo), R. Longo (Rome), K.-H. Rehren (Göttingen), J. Yngvason (Vienna)

Dates: August 25 - December 14, 2008

Budget: ESI €99.437,44

Preprints contributed: [2060], [2061], [2088], [2091], [2093], [2096]

Report on the programme

The scientific interaction between Quantum Field Theory and Mathematics has been fruitful over many decades. Algebraic Quantum Field Theory is one of the mathematically rigorous approaches to QFT and it is based on Operator Algebraic methods. The operator algebraic analysis of two-dimensional and chiral conformal quantum physics has been particularly fruitful in recent years. These theories are of interest both as models for quantum field theory itself and because of their relations to critical statistical mechanics systems and to string theory. This program brought experts and young researchers on this operator algebraic approach and related other mathematical topics such as vertex operator algebras, quantum groups and subfactors.

Within the above subjects, modular tensor categories provide a unifying mathematical structure. Study of tensor categories in Algebraic Quantum Field Theory started with the classical work of Doplicher-Haag-Roberts on superselection sectors that culminated in the Doplicher-Roberts duality characterizing duals of compact groups. They originally worked on QFT on a Minkowski space of a higher dimension, and the adaptation to the low dimension case is more recent and revealed a surprisingly rich new structure. Fredenhagen-Rehren-Schroer studied the appearing braided tensor category of sectors and the associated braid group statistics. Independently, at the same time, Longo found relations to the Jones index and subfactor theory providing, in particular, a classification of the statistics for small index values.

The basic objects in this approach to Chiral Conformal Field Theory are local conformal nets of von Neumann algebras. An induction procedure for their representation theory has been introduced by Longo-Rehren and further studied by Xu and Böckenhauer-Evans-Kawahigashi. This opened a way to combinatorial studies of representation theory through modular invariant matrices, thus making contact with the classification results by Cappelli-Itzykson-Zuber and Gannon.

Modularity (and rationality in particular) of representation theory of local conformal nets has been studied by Kawahigashi-Longo-Müger by introducing a notion of complete rationality. Further studies by Xu and Longo-Xu on this property show that this is the right notion of rationality for local conformal nets. Studies of topological sectors by Longo-Xu and soliton sectors by Kac-Longo-Xu have given further developments.

All this has recently led to the classification of local conformal nets of von Neumann algebras with central charge less than one by Kawahigashi-Longo with the construction of new unexpected models. Indeed, on the same line, F. Xu has very recently constructed infinitely many new models. The above classification result has also solved an open problem on a classification of certain vertex operator algebras arising from the Virasoro algebra. Related classification results for Full Conformal Field Theory and Boundary Conformal Field Theory have also been established, the latter being based on the framework of Longo-Rehren. A classification in the case of central charge one has been pursued independently by Carpi and Xu.

As a parallel development, the study of vertex algebras has been developed by Borcherds, Zhu, Dong, and others. Vertex algebras formalize the operator product expansion of local conformal fields, but are more flexible objects, admitting also non-unitary representations. Zhu has introduced the notion of C_2-cofiniteness and proven that a vertex algebra V is C_2-cofinite iff the associated algebra $A(V)$ is finite-dimensional and V has finitely many modules. It is quite apparent that there is a close resemblance to complete rationality in the algebraic approach, but the precise correspondence is not understood, due to the inequivalent set of underlying axioms. Nevertheless, working with Zhu's algebra $A(V)$ has many advantages as compared to the vertex algebra itself, and it seems promising to understand the analogue of $A(V)$ in algebraic QFT. Conversely, whereas orbifold and coset constructions of AQFT have their natural counterparts with vertex algebras, the "mirror extensions" recently discovered by Xu in the setup of AQFT are still lacking a counterpart, and are expected to give rise to new families of vertex algebras.

Another parallel development focuses on the functorial interpretation of QFT, emphasizing in the conformal case the possibility to define it on Riemann surfaces with and without boundaries and punctures. This point of view opens two very interesting perspectives: one towards elliptic cohomology (Stolz and Teichner), where a conformal QFT is viewed as a functor between a cobordism category and the category of vector spaces, thus encoding highly nontrivial cohomological information; the second (pursued by Fuchs, Runkel, Schweigert et al.) towards the purely categorial formulation of the consistency conditions arising when the surface changes ("sewing constraints" etc.). The latter approach has its natural counterpart within the Doplicher-Haag-Roberts tensor category of superselection sectors; yet some of the classification results obtained by Fuchs-Runkel-Schweigert are lacking a compelling interpretation in terms of local algebras. It appears that an extended version of the Principle of General Covariance in AQFT (Brunetti-Fredenhagen-Verch) should control the insertion of boundaries and punctures, and that Haag duality is related to the solvability of the constraints.

Yet another area of interest is the classification of finite index subfactors. Such subfactors arise as the objects of the DHR category, and also as local or nonlocal extensions of completely rational local nets; but there exist many more subfactors without a direct occurrence in QFT, which are of autonomous interest to mathematicians.

All these approaches contain as special models local current and Virasoro algebras and mathematical structures associated with them, but the respective generalizations and formalizations open into complementary directions. There are many striking analogies between these theories, but as many open questions concerning the precise relationships. It was the main purpose of the Workshop to bring together experts from the various lines of research and to strengthen the scientific exchange among them, notably between those rooted in Physics and those rooted in Mathematics.

The first main activity of the program was a two-week workshop "Operator Algebras, Conformal Field Theory and Related Topics", held September 8–19, 2008, with approximately 50 participants (some only for one week), and it covered a wide range of topics related to the above description of the recent development such as various applications in QFT, vertex algebras, noncommutative geometry, modular categories, subfactors and elliptic cohomology. There were 29 one-hour talks in the workshop. It was particularly gratifying to observe that in spite of the diversity of subjects, the talks were attended by experts in all fields; they incited discussions among participants with different backgrounds, trying to understand what their colleagues are doing in their approaches. The interdisciplinary character of the workshop was explicitly acknowledged and praised by many participants.

Another aim of the program to deepen connections with Connes' Noncommutative Geometry. Recently Kawahigashi-Longo showed that the Monstrous Moonshine can be also studied within an operator algebraic approach and further exploitation in connection to modular functions is expected, possibly using an approach of Dong-Xu. It would be of much interest to clarify the relation between this appearance of modular functions and another appearance in noncommutative geometry. Another line of research related to noncommutative geometry concerns asymptotic formulas for dimension, topological sectors, QFT index theorems and relations to black hole entropy (Kawahigashi, Longo, Xu); the noncommutative geometric insight offers perspectives for further analysis.

To achieve this aim, the second period of concentrated activity "CFT: Relations to Subfactors and Noncommutative Geometry" started on November 3. Vaughan F. R. Jones gave an Erwin Schrödinger Lecture, "Flatland, a great place to do algebra" on November 4, and Feng Xu gave a lecture series (8 two-hour lectures) on "Operator Algebras and QFT". His two main topics, namley the constructive use of operator algebras in conformal QFT, and the appearance of new types of intermediate subfactor lattices, demonstrate the cross-fertilization between Physics and Mathematics. Moreover, Nigel Higson gave 6 two-hour lectures on "Index theory, groupoids and noncommutative geometry". Both lecture series attracted attendance of up to forty, mostly young, people. Carpi, Hillier, Kawahigashi and Longo completed a related preprint "Spectral triples and the super-Virasoro algebra" in this period.

Invited Scientists: Toshiyuki Abe, Drazen Adamovic, Marta Asaeda, Paolo Aschieri, Bojko Bakalov, Katrina D. Barron, Daniel Beltita, Moulay-Tahar Benameur, Dietmar Bisch, Henning Bostelmann, Arnaud Brothier, Romeo Brunetti, Detlev Buchholz, Bernhard Burgstaller, Daniela Cadamuro, Valerio Capraro, Alain Carey, Sebastiano Carpi, Michele Cascarano, Marie Choda, Erik Christensen, Fabio Cipriani, Roberto Conti, Joachim Cuntz, Alessandro D'Andrea, Claudio D'Antoni, Annalisa Degan, Sergio Doplicher, George Elliott, David E. Evans, Klaus Fredenhagen, Jürgen Fuchs, Terry Gannon, Pinhas Grossman, Daniele Guido, Rudolf Haag, Andre Henriques, Nigel Higson, Robin Hillier, Masaki Izumi, Christian Jäkel, Vaughan Jones, Pierre Julg, Yasuyuki Kawahigashi, Alexander Kirillov, Hideki Kosaki, Thomas Krajewski, Alan Ch. L. Lai, Giovanni Landi, Gandalf Lechner, Fedele Lizzi, Roberto Longo, Pierre Martinetti, Toshihiko Masuda, Taku Matsui, Antonia Miteva, Valter Moretti, Gerardo Morsella, Michael Müger, Pieter Naaijkens, Nikolay Nikolov, Henrik D. Petersen, Valentina Petkova, Nicola Pinamonti, Paulo Pinto, Stephan Rave, Florin Radulescu, Karl-Henning Rehren, Andreas Recknagel, John Roberts, Stefano Rossi, Eric Rowell, Ingo Runkel, Nobuya Sato, Jean Luc Sauvageot, Martin Schlichenmaier, Christoph Schweigert, Urs Schreiber, Oleg Scheinman, Amandip Singh Sangha, Michael Stiller, Rolf Dyre Svegstrup, Masamichi Takesaki, Yoh Tanimoto, Reiji Tomatsu, Rainer Verch, Anatoly Vershik, Dan Voiculescu, Antony Wassermann, Mihaly Weiner, Hans Wenzl, Feng Xu, Shigeru Yamagami, Hiroshi Yamauchi, Jakob Yngvason, Pasquale Zito, Laszlo Zsido

Workshops Organized Outside the Main Programmes

Winter School in Geometry and Physics, Srni (Czech Republic)

Organizers: P. Michor (University of Vienna), J. Slovak (Masaryk University), V. Souček (Charles University)

Dates: January 12 - 19, 2008

Budget: Budget contribution by the ESI €1.000,–

Report on the programme

This traditional conference has taken place each January since 1980 for one week in a picturesque village in the Czech part of the Bohemian mountains. Since 1994 it has been a joint enterprise of the Czech Society of Mathematicians and Physicists and the Erwin Schrödinger International Institute for Mathematical Physics.

Proceedings have appeared in Arch. Math. (Brno) vol. 44, no. 5, 2008, available online at http://www.emis.de/journals/AM/08-5/index.html

Tensor Network Methods and Entanglement in Quantum Many-Body Systems

Organizers: F. Verstraete (Vienna), G. Vidal (Brisbane), M. Wolf (Copenhagen)

Dates: January 16 - 18, 2008

Budget: ESI €10.440,–

Report on the programme

Scope: The workshop held in January 2008 was aimed at bringing together the researchers working on the interface of quantum entanglement theory and quantum many-body systems on a lattice. Of specific interest were the new methods recently developed for simulating quantum spin systems: those include matrix product states, projected entangled pair states and the multiscale entanglement renormalization ansatz all these approaches can be subsumed under tensor network methods. Those topics get a lot of attention recently, and one of the main contributing factors is that they raise timely and interesting questions that are of interest to many communities such as condensed matter physics, statistical physics, mathematical physics, field theory, quantum chemistry, and quantum information.

Background: The notorious complexity of quantum many-body systems on a lattice stems to a large extent from the exponential increase of the Hilbert space dimension with increasing system size. This lets naive brute force approaches (e.g. based on exact diagonalization) fail from the beginning and classical techniques to overcome this issue (e.g. mean-field or Monte Carlo methods) often fail due to quantum correlations in the systems (eventually leading to a sign problem for Monte Carlo techniques). In the last years it become more and more clear that the majority of states in Hilbert space is, however, irrelevant for physical problems related to (quasi-)local Hamiltonians. It is therefore desirable to look for efficient representations of the 'relevant corner' in Hilbert space. Motivated by insights from entanglement theory and information theory, tensor network representations were developed to achieve this goal. The name 'tensor network' comes from regarding the coefficients of an n-partite pure quantum state (when expanded in computational basis) as an n'th order tensor for which a simplified ansatz in terms of a contracted network of smaller tensors is used. The contraction pattern in this network may resemble the geometry of the lattice (as usually in projected entangled pair states - PEPS) or it may be chosen ad hoc in order to grasp the correct scaling behavior of correlations (as in the multi-scale entanglement renormalization ansatz - MERA). In any case the ansatz is chosen such that the number of parameters grows only polynomial with the system size (or is even constant in the translational invariant case) while the state still captures the essential properties of the exact solution. Tensor network representations are usually part of a hierarchy in which the lowest level contains all product states and the highest level all states in Hilbert space. The applications of tensor network representations are both numerical and analytic. On the numerical side the simplest question to tackle is to find the ground state of a (quasi-)local Hamiltonian. In this case states within a certain level are used as variational ansatz. The tools developed in this direction can, however, as well be used for determining Gibbs states, excitations or time evolutions. On the analytical side the lower levels of the hierarchy can (together with the respective parent Hamiltonans) be used as quasi-exactly solvable toy models to answer questions which are often too difficult to be answered in general.

Special topics and subsequent results: The workshop contained few organized talks and had lots of room for discussions that were sometimes initiated by informally given talks (making heavily use of the miles of blackboards which decorate the Institute). During the latter the following topics played a dominant role: (i) combining tensor networks with Monte Carlo methods: As outlined in a talk given by A. Sandvik and also informally discussed on the basis of work by Schuch et al. the problem of not being able to perfectly contract a tensor network can partially be overcome by restricting to classes of stats for which each entry of the tensor can be efficiently computed using Monte Carlo sampling. (ii) computational complexity: part of the informal discussion was concerned with the question about the computational complexity of finding the tensor network (matrix product) representation of a ground state. In general this turns out to be a hard problem for which no efficient algorithm is assumed to exist. However, in practice hard instances seem not to appear (the difficulty might be partially cured by translational invariance). (iii) special properties of tensor network states: the elementary tensors of the network encode all properties of the state. It is therefore a natural question how special properties are reflected on this level. During the workshop in particular local symmetries, string order, and topological properties were intensively discussed. Based on the ideas developed at the ESI, the former are in the meanwhile rather exhaustively characterized (Perez-Garcia et al., see below and to be published).

It was the unanimous opinion of the participants that the Institute provides a very stimulating environment, and the workshop resulted in several new collaborations. Specific examples of papers that were conceived at the workshop are:

String order and symmetries in quantum spin lattices D. Perez-Garcia, M.M. Wolf, M. Sanz, F. Verstraete, J.I. Cirac, Phys. Rev. Lett. 100, 167202 (2008)

The computational difficulty of finding MPS ground states Norbert Schuch, Ignacio Cirac, Frank Verstraete Phys. Rev. Lett. 100, 250501 (2008)

Invited scientists: Thomas Barthel, Bela Bauer, Ignacio Cirac, Phillippe Corboz, Gregory Crosswhite, Wolfgang Dür, Jens Eisert, Hans Gerd Evertz, Juanjo Garcia-Ripoll, Eric Jeckelmann, Ying-Jer Kao, Jose Ignacio Latorre, Ors Legeza, Lluis Masanes, Simone Montangero, Valentin Murg, Reinhard Noack, Roman Orus, Tobias Osborne, David Perez-Garcia, Peter Pippan, Enrique Rico-Ortega, Matteo Rizzi, Anders Sandvik, Ulrich Schollwöck, Norbert Schuch, Luca Tagliacozzo, Matthias Troyer, Frank Verstraete, Guifre Vidal, Michael Wolf

Intermetallics

Organizer: J. Hafner (Vienna)

Dates: January 23 -24, 2008

Budget: Externally financed

Report on the programme

The aim of this workshop was to bring together researchers from the Center for Computational Materials Science and from universities and academy research institutes in neighboring countries working on ab-initio density-functional studies of intermetallic compounds. Fruitful cooperations between these research groups have already existed for some time and the workshop has contributed to intensify these links. The workshop was opended with a talk by Prof. Mojmir Šob (Brno) reviewing the state of the art in the field. Topical session were devoted to the investigation of phase stabilities, lattice defects, mechanical properties, magnetism, and to quasicrystalline alloys.

A list of all contributions follows:

A) **Introduction:**
M. Šob, M. Friak, D. Legut, J. Kuprilach, I. Turek (all Masaryk University and Institute for Materials Physics, Czech Academy of Sciences, Brno) and V. Vitek (University of Pennsylvania): Application of ab-initio methods to studies of the properties of metallic materials.

B) **Structure and phase stability:**
D. Reith (Unveristät Wien and CMS): Ab-initio modeling of Fe-rich Fe-Cu alloys.
M. Stöhr (Universität Wien and CMS): Cluster expansion studies of bulk alloys and alloy surfaces.
M. Všianská, D. Legut, M. Šob (Masaryk University and Institute for Materials Physics, Czech Academy of Sciences, Brno): Electronic structure of indium-tin alloys.

C) **Lattice defects**
A. Kiejna (University of Wroclaw): Cohesion and impurity segegation at grain boundaries in iron.
T. Ossowski (University of Wroclaw): Cohesion at chromium grain boundaries.
E. Wachowicz (University of Wroclaw): The effect of various impurity concentration on the $\Sigma5$ Fe(210) grain boundary.

D) **Mechanical properties:**
M. Jahnatek (Universität Wien and CMS): Ab-initio modeling of the response of intermetallics to tensile and shear loading.
P. Lazar (Universität Wien and CMS): Improving ductility by microalloyng: an ab-initio study for NiAl.

E) **Magnetism:**
P. Mohn (Technische Universität Wien and CMS): Magnetism without d- and f-electrons.
P. Blonski (Universität Wien and CMS): Structure and magnetism of small transition-metal clusters.
M. Zeleny, M. Šob (Masaryk University and Institute for Materials Physics, Czech Academy of Sciences, Brno), J. Hafner (Universität Wien and CMS): Ab-initio study of structural and magnetic properties of iron nanowires.

F) **Quasicrystals:**
M. Krajčí (Institute of Physics, Slovak Academy of Sciences, Bratislava and CMS): Quasicrystals: Structure and properties of bulk, surface and thin films.
J. Hafner (Universität Wien and CMS): Adsorption of atoms and small molecules on quasicrystalline surfaces.

Invited scientists: Piotr Blonski, Pavlina Elstnerova, Michal Jahnatek, Adam Kiejna, Marian Krajčí, Petr, Lazar, Peter Mohn, Tomasz Ossowski, David Reith, Mojmir Šob, Markus Stöhr, Monika Všianská, Elwira Wachowicz, Martin Zeleny

ESI - 15th Anniversary Celebration

Organizers: W.L. Reiter (Vienna), K. Schmidt (Vienna), J. Schwermer (Vienna), J. Yngvason (Vienna)

Date: April 14, 2008

Budget: ESI € 7.331,01

On April 14, 2008, the ESI celebrated its 15th anniversary with a series of lectures by distinguished scientists on topics ranging from ultra cold atoms, supergravity, quantum ideas in number theory, the Langlands' programme, mirror symmetry and mathematical biology.

Programme

Rudolf Grimm (Innsbruck): "Ultracold Atoms: New Light on Few- and Many-Body Phenomena"

Thibault Damour (IHES, Bures-sur-Yvette): "Chaos and Symmetry in Gravity and Supergravity"

Don Zagier (College de France, Paris and MPIM, Bonn): "Quantum Ideas in Number Theory and Vice Versa"

Edward Frenkel (Berkeley): "Geometric Langlands Program and Mirror Symmetry"

Steven N. Evans (Berkeley): "What has 'Life' Done for Me Lately"

The last of these lectures also opened the subsequent Workshop on 'Frontiers in Mathematical Biology', which continued with a keynote lecture by Peter Schuster (Austrian Academy of Science, Vienna) on 'The Advantage of Using Mathematics in Biology'.

Frontiers in Mathematical Biology

Organizers: R. Bürger (Vienna), J. Hermisson (Vienna)

Dates: April 14 - 18

Budget: ESI € 7.165,23, WWTF € 1.758,80

Preprint contributed: [2037]

Report on the programme

The actual workshop was preceded by two keynote opening lectures that were presented as part of ESI's 15th Anniversary Celebration. In his lecture "What has "Life" done for me lately", the title alluding to Schrödinger's well known book, Steven N. Evans (Berkeley) described how biologically motivated questions have led to a variety of interesting mathematical problems and beautiful results. Complementary, Peter Schuster (Vienna) presented a number of topics from evolutionary and molecular biology, as well as chemistry, that demonstrate "The advantage of using mathematics in biology". Whereas these keynote lectures aimed to reach a broad scientific audience, and were very well attended by mathematicians, physicists, and other scientists, the workshop talks were much narrower in focus.

The workshop was dedicated to recent developments in stochastic and spatial models in population genetics. The talks (see enclosed list) were delivered by leading mathematicians and geneticists in the field. Probabilistic models in population genetics have a long history, going back to R.A. Fisher and S. Wright in the 1920s and 1930s. The first, who formulated and analysed such models as stochastic processes in the modern sense, was the French mathematician G. Malécot (in the 1940s). Since then an enormous development took place, both from a mathematical as well as from an applied perspective. In the last decade, however, the ever faster-growing flow of data from molecular biology led to a new twist in theory development. Based on generalizations of what is now called the Kingman coalescent, it became feasible to use genetic data from extant populations to infer evolutionary events in their past. The reason is that processes such as selection, mutation, recombination, or population growth leave certain 'footprints' in the genomes of modern populations. To obtain valid inferences about selection or about the demographic history of a population, new mathematical models and ideas have (and had) to be developed. In addition, the analysis of molecular data as well as of computer- generated output of the complex stochastic models requires new statistical tools. More than half of the talks in this workshop reported about stochastic processes or statistical methods to treat such kind of problems.

Most other talks were concerned with spatial models, some combining spatial and stochastic aspects. The importance of geographic structure and spatially varying selection has been recognised from early on, notably by J.B.S. Haldane and, again, by Fisher and Wright. Models are formulated in terms of partial differential equations (if individuals 'diffuse' through a connected habitat) or in terms of ordinary difference- or differential equations (if individuals migrate between distinct niches). Both types of approaches were covered and two different types of questions were asked and treated. The first concerned predictions about the evolutionary fate of structured populations as a function of the migration and selection properties, the second concerned inference processes of the kind outlined above, but in a structured population. Extensive and engaged discussions complemented the talks and new routes for future research were suggested.

Speakers and talks:

Steven N. Evans (Berkeley): What has 'Life' done for me lately?
Peter Schuster (Vienna): The advantage of using mathematics in biology.
Ellen Baake (Bielefeld): Stochastic and deterministic aspects of recombination.
Nick Barton (Edinburgh): A limit to the rate of adaptation.
Matthias Birkner (Bonn): Inference for lambda-coalescents.
Reinhard Bürger (Vienna): Multilocus migration-selection models.
Alison Etheridge (Oxford): A new model for evolution in a spatial continuum.
Bob Griffiths (Oxford): Harmonic measure and fixation probabilities of types for genetic drift.
Thomas Lenormand (Montpellier): An alternative theory for the dominance of mutations.
Judith Miller (Georgetown U): Inference of selection on quantitative traits in subdivided populations.
Peter Pfaffelhuber (Freiburg): Approximating genealogies under genetic hitchhiking with recurrent mutation.
François Rousset (Montpellier): Multilocus models in spatially structured populations.

Hamish Spencer (U of Otago): Population structure and the maintenance of genetic variation.
John Wakeley (Harvard U): Conditional gene genealogies under strong purifying selection.
Anton Wakolbinger (Frankfurt): How often does the ratchet click?
Anita Winter (Erlangen): Coalescent trees and their evolution.
Carsten Wiuf (Aarhus): Parametric inference in coalescent models.

Invited Scientists: Ellen Baake, Nick Barton, Matthias Birkner, Reinhard Bürger, Alison Etheridge, Steve Evans, Bob Griffiths, Joachim Hermisson, Thomas Lenormand, Judith Miller, Peter Pfaffelhuber, Francois Rousset, Hamish Spencer, John Wakeley, Anton Wakolbinger, Anita Winter, Carsten Wiuf

Summer School on "Combinatorics and Statistical Mechanics"

Organizers: C. Krattenthaler (Vienna),

Dates: July 7 - 18, 2008

Budget: ESI €2.610,–, FWF and EU Networks €13.410.–

Report on the programme

The aim of this summer school was to introduce Young Researchers at the PhD and postdoc level to exciting recent developments of current research at the crossroads of Combinatorics and Statistical Physics. The school was attended by about 35 young researchers at the Ph.D. student respectively post-doc level. During this school, 4 lecture courses were given, as listed below. These courses also included extensive exercise sessions, in order to give the Young Researchers a true feeling and understanding of the presented material.

A short summary of thecourses given follows:

Philippe Di Francesco: "Integrable Models of Statistical Physics and Enumerative Combinatorics"

These lectures centered around the mysterious links between Alternating Sign Matrices and Totally Symmetric Self-Complementary Plane Partitions, and they highlighted the power of quantum integrability.

John Imbrie: "Combinatorial Aspects of Mayer Expansions, Forest Formulas, and Grassmann Integrals"

A number of traditional tools of statistical mechanics and quantum field theory have been redeveloped and combined in recent years to provide new insights into the behavior of generating functions in stochastic geometry. These lextures surveyed these tools and applied them to a number of interesting examples. Keywords for this course were: Mayer expansions; combinatoric aspects of convergence. A forest-root formula for directed branched polymers. Applications of Grassmann integrals to statistical mechanics. a. The matrix-tree theorem and a supersymmetric forest-root formula. Branched polymers and dimensional reduction. b. Combinatoric aspects of the self-avoiding walk.

Christian Krattenthaler: "Asymptotic Properties of Tilings"

Rhombus tilings and domino tilings are frequently studied models in statistical physics and combinatorics. Both are, in fact, equivalent to dimer models, that is, to models of covering certain planar graphs by sets of dimers (pairwise disjoint edges), so-called dimer coverings. Several scattered results exist on "arctic circles" and "typical shapes" of special dime models. A very general theorem in this direction has been proven for square grids by Cohn, Kenyon ad Propp. This paved the way for Kenyon, Okounkov and Sheffield to lift this theory to dimer coverings of a large class of periodic planar graphs. This theory includes results about typical shape and frozen boundaries, as well as a complete classification of the different phases of the model which may occur. This is a fascinating, beautiful theory at the interface of enumerative combinatorics, probability, and statistical physics, which requires a large set of tools ranging from analysis, tools from the mentioned areas, up to tools from algrbraic geometry.

The lecture series provided a survey of this theory, mainly concentrating on the work by Cohn, Kenyon and Propp, but with a view towards the extensions and generalizations by Kenyon, Okounkov and Sheffield.

Thomas Prellberg: "Combinatorial Enumeration with the Kernel Method"

In recent years the kernel method, a well-known method in algebraic combinatorics for solving functional equations, has been extended significantly, and enables the derivation of generating functions for a variety of combinatorial and statistical mechanical problems. Examples for the range of its application are various lattice walk models, enumeration of parking functions (or equivalently, hashing with linear probing), and the Potts-q random matrix model.

This series of lectures presented the kernel method in its various disguises, along with pedagogical examples for each of these. We shall examine the question of whether the generating functions obtained are rational, algebraic, differentiably finite, or neither. Naturally, this has important consequences for the singularity structure of the generating functions, and therefore for the asymptotic behaviour of its coefficients.

Furthermore, the applicability of competing methods was highlighted. Finally, counting problems leading to q-deformations were discussed.

Summer School on "Current Topics in Mathematical Physics"

Organizers: C. Hainzl (Birmingham, Alabama), R. Seiringer (Princeton), J. Yngvason(Vienna)

Dates: July 21 - 31, 2008

Budget: ESI €50.238,08

Preprints contributed: [2030], [2050], [2052], [2056], [2085], [2114]

Report on the programme

From July 21–31 2008, the ESI hosted a summer school on current topics in mathematical physics. During these two weeks there were 8 lecture series delivered by experienced and prominent scientists. Among the topics were large quantum systems, random Schrödinger operators, quantum information theory, general relativity and methods in the calculus of variations. There is currently intense research on all these topics and the summer school presented a great opportunity to learn about new developments.

In the following, a brief description of the content of the lecture series is given.

- **László Erdős** (LMU Munich): *Quantum Brownian motion as a scaling limit of random Schrödinger evolution.* Einstein's kinetic theory of the Brownian motion, based upon light water molecules continuously bombarding a heavy pollen, provided an explanation of diffusion from the Newtonian mechanics. Since the discovery of quantum mechanics it has been a challenge to verify the emergence of diffusion from the Schrödinger equation. The first step in this program is to verify the linear Boltzmann equation as a certain scaling limit of a Schrödinger equation with random potential. In the second step, one considers a longer time scale that corresponds to infinitely many Boltzmann collisions. The intuition is that the Boltzmann equation then converges to a diffusive equation similarly to the central limit theorem for Markov processes with sufficient mixing. The mathematical tools to rigorously justify this intuition were presented in these lectures.

- **Vojkan Jaksic** (McGill University): *Entropic fluctuations in statistical mechanics.* In the past 10–15 years there has been a strong revival in nonequilibrium statistical mechanics, with an emphasis on systems which are driven and maintained out of equilibrium and characterized by steady flows of energy and/or matter. The progress was driven, on one hand, by numerous numerical experiments and theoretical ideas in (finite-dimensional) hyperbolic dynamics and, on the other hand, by advances in the dynamics of infinite Hamiltonian systems (open systems). Prominent among these new results is an universal symmetry of the fluctuations of the entropy production rate for a system driven out of equilibrium. In these lectures deterministic dynamical systems were discussed and a framework within which open infinite systems and thermostated finite dimensional systems can be treated in a unified manner was described.

- **Igor Rodnianski** (Princeton): *Evolution problem in General Relativity.* In these lectures the Cauchy problem for Einstein's equations of general relativity was discussed. Various aspects of stability of Minkowski und black-hole spacetimes were investigated. As a first step towards understanding these questions, one studies solutions of the (linear) wave equation on non-trivial spacetime backgrounds.

- **Manfred Salmhofer** (Leipzig): *Renormalization group methods for quantum many-body systems.* The method of renormalization group has proved very fruitful in understanding various properties of quantum many-body systems and quantum field theory. In these lectures an elementary introduction to the ideas and applications of the renormalization group was given. Special emphasis was on fermionic lattice systems with finite range interactions.

- **Herbert Spohn** (TU Munich): *Kinetic theory of weakly interacting quantum fluids.* The derivation of the Nordheim-Boltzmann transport equation for weakly interacting quantum fluids is a longstanding problem in mathematical physics. Inspired by the method developed to handle classical dilute gases, a conventional approach is the use of the BBGKY hierarchy for the time-dependent reduced density matrices. In contrast, the approach in these lectures is motivated by the kinetic theory of the weakly nonlinear Schrödinger equation. The main observation is that the results obtained in the latter context carry over directly to weakly interacting quantum fluids provided one does not insist on normal order in the Duhamel expansion.

- **Bruno Nachtergaele** (UC Davis): *Quantum Lattice Dynamics and Applications to Quantum Information and Computation.* These lectures covered various topics of relevance for quantum spin systems. These include Lieb-Robinson bounds (both for lattice systems with bounded interactions and (an)harmonic lattice systems), the exponential clustering theorem (relating the spectral gap and the correlation length in ground states), and the area law for the local entropy and related questions concerning the structure of gapped ground states. Moreover, a Lieb-Schultz-Mattis theorem in general dimensions was discussed.

- **Jeffrey Schenker** (Michigan State): *On random Schrödinger operators.* Various aspects of Schrödinger operators with random external potential were considered. In particular, the phenomenon of Anderson localization and our current rigorous mathematical understanding of it was discussed. A detailed description of the "augmented space formalism" to prove diffusion for the Markov-Anderson model was given.

- **Michael Loss** (Georgia Tech): *A dynamical approach to some problems in the calculus of variations.* These lectures focused on functional inequalities, like Hardy-Littlewood-Sobolev, Gagliardo-Nirenberg and Brascamp-Lieb inequalities. The question about sharp constants in these inequalities is an optimization problem and a dynamical approach to the solution of these problems was presented. The main idea is that there exists a discrete or continuous flow under which the quotient of the variational problem behaves in a monotone way. The construction of these flows depends on the problem at hand and three different choices based on symmetrization, on fast diffusion and on a non-linear heat flow, were explained. Key points in the proof as well as the underlying heuristic motivation were presented and, without requiring prerequisites, the participants were given an overview over this elegant approach.

Each lecture series consisted of 4 lectures of 1 hour each, which gave the speakers enough time to present the material in a comprehensive and pedagogical way.

Besides the speakers and the organizers, there were 50 participants in the summer school, which are listed below. The participants consisted mostly of advanced graduate students, post-docs or young researchers on the assistant professor level. Some of the graduate students were given the opportunity to present their work in a 30 minute talk.

Invited Scientists: Riccardo Adami, Paolo Antonelli, Sven Bachmann, Susanne Barisch, Laurent Bruneau, Horia Cornean, Giuseppe de Nittis, Jeremy Faupin, Soren Fournais, Rupert Frank, Abraham Freiji, Alessandro Giuliani, Andreas Grotz, Christian Hainzl, Florina Halasan, David Hasler, Yang Kang, John Kerl, Antti Knowles, Helge Krueger, Vincent Larochelle, Enno Lenzmann, Mathieu Lewin, Jani Lukkarinen, Alessandro Michelangeli, Johanna Michor, Tadahiro Miyao, Irina Nenciu, Annalisa Panati, Gianluca Panati, Federica Pezzotti, Alessandro Pizzo, Olaf Post, Emil Prodan, Morten Rasmussen, Hillel Raz, Jacob Schach-Moller, Daniela Schiefeneder, Benjamin Schlein, Robert Seiringer, Roman Shterenberg, Viacheslav Shtyk, Robert Sims, Thomas Sorensen, Christof Sparber, Wolfgang Spitzer, Shannon Starr, Edgardo Stockmeyer, Stefan Teufel, Daniel Ueltschi, Jakob Wachsmuth, Claudia Warmt

Mathematical General Relativity

Organizers: R. Beig (Vienna), J.M Heinzle (Vienna)

Dates: August 20 - 21, 2008

Budget: ESI € 1.080,–

Report on the programme

The conference “Developments in Mathematical Relativity” was a two-day conference on mathematical general relativity. There were eight invited speakers—four talks per day, and about 30 participants. Many of the speakers and participants were colleagues and collaborators of Robert Beig (Gravitational Physics, Faculty of Physics, Univ. Vienna), whose sixtieth birthday was at the same time celebrated.

After a brief welcome to the conference, the opening talk was given by Sascha Husa (Univ. Mallorca), who talked about different slicings by spacelike hypersurfaces, which are useful in recent numerical evolutions of black hole spacetimes. The second talk of the first session was given by Juan Valiente Kroon (Queen Mary, London), who reviewed characterizations of spacetimes, in particular Schwarzschild, in terms of initial data sets.

The speakers of the second session were Helmut Friedrich (MPI for Gravitational Physics) and Piotr Chruściel (Oxford). Helmut Friedrich discussed the intricacies of the initial boundary value problem for the Einstein vacuum equations, in particular the open problem therein of proving a uniqueness theorem in geometrical terms. Piotr Chruściel’s talk was split in two parts. The first part highlighted Robert Beig’s contributions to the field of mathematical relativity. The second part described recent developments leading to new inequalities which bound angular momentum in terms of mass.

The second day of the conference began with a talk by Lars Andersson (MPI for Gravitational Physics) who described recent work of his on the structure of the region of spacetime containing trapped surfaces. László Szabados (Hungarian Academy of Sciences, Budapest) discussed successes and difficulties in the program of formulating a Hamiltonian theory of GR purely on the quasi-local level.

The last session of the conference consisted in talks by Bernd Schmidt (MPI for Gravitational Physics) and Niall Ó Murchadha (Univ. Cork). Bernd Schmidt revisited Bondi's negative-mass two-particle solutions in GR and the prospect of replacing the particles in these solutions by finite elastic bodies. Niall Ó Murchadha, complementing Husa's talk, discussed spherical constant mean curvature slicings of the Schwarzschild spacetime.

Mathematical Challenges in String Phenomenology

Organizers: R. Blumenhagen (München), M. R. Douglas (New York), M. Kreuzer (Vienna), E. Scheidegger (Augsburg)

Dates: October 6 - 17, 2008

Budget: ESI € 21.895,06

Preprints contributed: [1992], [2005], [2089], [2100], [2104], [2105], [2106],[2108], [2110], [2123]

Report on the programme

This programme brought together leading experts working on different mathematical aspects of string phenomenology. The activities of this area of research have become more and more intense with the expected advent of the LHC in 2008. String phenomenology deals with the implications of (super)string theory at low energies. In this regime, ten-dimensional space-time of superstring theory is "compactified" to our four-dimensional Minkowski space-time, where the geometry of the internal space determines the parameters in the four-dimensional low-energy effective action.

For the description of such compactifications, various mathematical structures are needed depending on the choice of the parameters of the theory. Working in the large radius, supergravity regime, of the internal manifold, the stringy nature can be neglected and the compactifications are described in geometric terms, where methods of topology and geometry, both differential and algebraic are relevant. For example, in heterotic string compactifications without fluxes, one needs to specify a Calabi-Yau manifold together with a stable vector bundle satisfying certain consistency conditions. Turning on fluxes, these conditions become much more involved.

At small scales of the underlying geometry, stringy aspects must not be neglected any more. This is naturally taken care of by two-dimensional conformal field theories that include perturbative string and world-sheet instanton corrections which leads to the realm of mirror symmetry. The natural set-up in which these corrections can be studied in detail are type II compactifications with D-branes and orientifolds. In this context, the natural mathematical language turns out to be Landau–Ginzburg models (singularity theory) and matrix factorizations for the D-branes. If also the string coupling is not perturbatively small, string loop and space-time instanton corrections have to be considered.

Once a compactification is specified it is important to study the effective four-dimensional theory. An important step towards a predictive framework is to understand the dynamics of so-called moduli fields which are fields that are massless at leading order and whose vacuum expectation values determine the parameters of the low-energy theory such as gauge couplings, Yukawa couplings etc. A very successful approach in the past year have been (local) F-theory compactifications which formed a central topic of the workshop.

For the generation of potentials for these moduli, various new mechanisms have been under investigation during the past years, which extended the set of possible compactifications considerably. The two main mechanisms are fluxes of differential forms and non-perturbative instanton corrections. This area of reasearch has led to new types of background "geometries" for compactifications like generalized complex geometries and non-geometric compactifications such as T-folds.

In most of these cases, the choice of compactification is far from being unique. It is therefore important to turn the various mathematical descriptions of these compactifications into algorithms which allow for the enumeration of these choices, and the selection of preferred choices, e.g. those that lead to a deired potential or a particular Yukawa coupling.

The main topics of the workshop were:

- Heterotic string compactifications
- D-brane constructions
- Generalized geometries
- LG models and matrix factorisations
- F-theory and GUTs
- Computational aspects

In the following we describe the contributions to the topics during the workshop.

1. Heterotic string compactifications:

In his lecture on heterotic string model building, A. Lukas gave an exhaustive review of all the basic aspects of heterotic string compactifications, mainly focusing on the Calabi–Yau case, from heterotic M-theory to new technniques in computing Yukawa couplings. V. Braun continued in his review with one of the central issues in heterotic string compactifications, namely the construction of stable vector bundles on Calabi–Yau threefolds. He focused on a particular example of a bundle on Schoen's Calabi–Yau threefold for which he was able to compute physically relevant qunatities such as μ–terms. L. Anderson, working on the same issue, considered instead a large class of monad bundles which can be dealt with algorihtmically. The remaining two talks showed the progress in the much less understood non-Calabi–Yau case, i.e. the so–called torsional backgrounds. M. Becker reviewed the torsional constraints and their known solutions and showed how to obtain new solutions by orbifolding. K. Becker presented a method to construct such torsional backgrounds starting from an elliptic Calabi–Yau fibration in M-theory and using various dualities.

2. D-brane constructions:

In his lecture on D-brane model building and instantons, A. Uranga reviewed the construction of semi-realistic compactifications using appropriate sets intersecting D-branes and discussed the various instanton effects that appear in these models, in particular the interplay with fluxes. A. Lerda and M. Billo summarized their techniques to compute amplitudes in instanton and D-instanton backgrounds they have developed over the past few years. This so-called "stringy instanton calculus" turns out to be an essential tool to devise the structure of non-perturbative contributions to the effective action for gauge theories engineered by D-brane constructions in a string compactification. M. Schmidt–Sommerfeld considered effects of multi-D-instanton on certain holomorphic quantities such as the gauge kinetic couplings and compared them to expectations from S–duality.

3. Generalized complex geometry:

In his lecture, C. Hull gave an overview of nongeometric string backgrounds. These include T-folds which are spaces similar to manifolds but use T-duality symmetries instead of diffeomorphisms to glue local coordinate charts together. These are natural further generalizations of the generalized geometries introduced by Hitchin. These generalized geometries were reviewed in the lecture by P. Koerber in which he explained how they solve the supersymmetry conditions in the presence of fluxes in type II compactifications, how they can be classified, and how D-branes can be described by generalized calibrated submanifolds. L. Martucci continued by addressing the issue of constructing the four-dimensional effective action in such compactifications. This involves an appropriate truncation of the 10-dimensional theory whose consistency has to be checked. The same issue was discussed by F. Witt from the purely mathematical point of view of constructing invariant functionals. D. Cassani, on the other hand, constructed the complete supersymmetric action in 4 dimensions by using the special Kähler structure of the space of the deformations of generalized geometries. From a more physical point of view, A. Kashani-Poor discussed how the fact that such compactifications lead to gauged supergravities can be used to obtain consistent truncations. Finally, A. Tomasiello reviewed in his lecture the classification of supersymmetric type II flux compactifications from the point of view of the AdS/CFT correspondence.

4. LG models and matrix factorisation:

M. Bianchi gave an extensive introduction to nongeometric compactifications with D-branes in terms of Gepner models and their boundary states. He explained how to compute tree level gauge couplings and their one-loop thresholds in type I compactifications. M. Herbst reviewed in his lecture Landau-Ginzburg models and the description of D-branes in terms of matrix factorisations and showed that they are alternative, more algebraic descriptions of the Gepner models and their boundary states, respectively. He further explained that D-branes in the gauged linear sigma model can also be described in terms of matrix factorizations and how they are related to the matrix factorizations in the Landau-Ginzburg model and the geometric description of the D-branes, in particular in the case of complete intersections. E. Scheidegger showed how to use this description of D-branes in the gauged linear sigma model to find differential equations for the domain-wall tensions of these D-branes using an extension of mirror symmetry to open string. H. Jockers presented a method to find these domain wall tensions arise as the critical points of effective superpotentials for compact Calabi-Yau geometries with D5-branes which he derived by extending N=1 special geometry to these geometries. D. Orlov gave a review of derived categories of singularities and explained their relation to the category of matrix factorizations.

5. F-theory and GUTs:

The most recent new development in the description of mathematical issues in string phenomenology was certainly the work by Beasley–Heckman–Vafa and Donagi–Wijnholt on the use of F-theory to describe GUT models and supersymmetry breaking therein. We were very lucky to have two of the pioneers of this approach at our workshop. In his lecture, C. Beasley explained the basics of F-theory and pointed out that in the limit of decoupling gravity all the properties of the GUT model follow from del Pezzo surfaces and the E_8 lattice which describe certain exceptional branes. While this can be seen as a bottom-up approach, Wijnholt took a top-down approach without insisting that gravity be decoupled and derived conditions to obtain GUT models from F-theory. S. Schäfer-Nameki explained how gauge meditation can be used to break SUSY in these local F-theory GUT models by considering various instanton conributions to the superpotential. T. Grimm presented new results on GUTs and SUSY breaking in orientifold limits of F-theory compactifications, in particular a systematic analysis of globally consistent GUT models (without decoupling gravity) on intersecting D7-branes in genuine Calabi-Yau orientifolds. A. Collinucci analyzed the properties of D7-branes in type IIB orientifolds and explained the correct way to deal with the singularities in the presence of O7-planes. A. Braun showed in a simplified model how the moduli of these D7-brane can be fixed by the choice of fluxes in F–theory which in turn determines the singularity structure of the compactification.

6. Computational Aspects:

In his lecture on aspects of algorithmic algebraic geometry in string phenomenology, J. Gray presented the software package called Stringvacua. Given a four dimensional N = 1 supergravity describing a flux compactification, he explained how the constraints on the flux parameters which are necessary and sufficient for the existence of a particular kind of vacuum can easily be found with the help of this package. A. Lukas explained some more basics about Groebner bases and other techniques in algorithmic algebraic geometry that form the software package Stringvacua. A different aspect of algebraic geometry was the focus in the review of M. Kreuzer on his work on toric geometry. He presented the software package PALP to analyze lattice polytopes that encode the combinatorial data of toric varieties. V. Braun explained how to apply Donaldson's algorithm to find Kähler metrics with constant scalar curvature to Calabi-Yau threefolds and with the help of this metric he went on to numerically determine the spectrum of the scalar Laplacian.

Invited Scientists: Lara Anderson, Bjorn Andreas, Christopher Beasley, Katrin Becker, Melanie Becker, Massimo Bianchi, Marco Billo, Ralph Blumenhagen, Andreas Braun, Volker Braun, Davide Cassani, Andres Collinucci, Ron Donagi, Michael R. Douglas, Richard Garavuso, James Gray, Thomas Grimm, Daniel Grumiller, Manfred Herbst, Chris Hull, Hans Jockers, Benjamin Jurke, Amir-Kian Kashani-Poor, Johanna Knapp, Paul Körber, Maximilian Kreuzer, Alberto Lerda, Andre Lukas, Luca Martucci, Ilarion Melnikov, Alexander Popolitov, Pavel Putrov, Radoslav Rashkov, Sakura Schafer-Nameki, Emanuel Scheidegger, Maria Schimpf, Maximilian Schmidt-Sommerfeld, Alessandro Tomasiello, Angel Uranga, Martijn Wijnholt, Frederik Witt, Timm Wrase

Structural Probability

Organizers: V. Kaimanovich (Bremen), K. Schmidt (Vienna)

Dates: November 3 - 14, 2008

Budget: ESI €24.463,35

Preprints contributed: [2063], [2065], [2068], [2069], [2087]

Report on the programme

The workshop was a continuation of a series of earlier programmes at ESI: special semester "Random Walks" (2001), RDSES/ESI Educational Workshop on Discrete Probability (2006), special semester "Amenability" (2007; in particular, the summer workshop "Algebraic, geometric and probabilistic aspects of amenability").

Recent developments show that probabilistic methods have become very powerful tools in such different areas as statistical physics, dynamical systems, Riemannian geometry, group theory, harmonic analysis, graph theory and computer science. Moreover, although classical "continuous models" remain, of course, in the mainstream of the probability theory, an important feature of a significant number of these applications is that the considered models deal with spaces endowed with appropriate geometric or algebraic structures (like graphs, networks, groups, manifolds etc.). *Structural probability* (the term is due to H. Heyer) is a branch of probability theory devoted to a study of qualitative aspects of the behaviour of probabilistic models on spaces endowed with additional structures (usually of geometric or algebraic origin) and to relating them with the structural properties of the state spaces. This branch is currently becoming more and more popular: at least 2 out of 4 Fields medals awarded in 2006 are directly related to this area.

Working in structural probability inevitably requires a combination of the appropriate probabilistic and geometric or algebraic approaches and methods. Note that, typically, discrete models are less "technical" and give an easier access to the nature of certain qualitative phenomena than continuous ones. One example is the very successful and active theory of random walks on groups, which combines ideas and methods from the general theory of Markov chains (recurrence, boundary theory, asymptotics of transition probabilities) with the specifics coming from the presence of a rich algebraic structure (amenability, growth, isoperimetry, concrete classes of groups).

Roughly speaking, there are two different ways in which randomness interacts with the structure. The structure itself can be deterministic, in which case its properties are exposed by considering various stochastic processes (usually, Markov ones, for instance, random walks or diffusion processes) on the state space which agree with its structure. Alternatively, probability can be used to produce random structures which sometimes is the only known way to construct structures with unusual properties (with examples ranging from Pinsker's construction of random expanders to the recent theory of random groups initiated by Gromov).

Of course, it was impossible to embrace all the aspects of the structural probability within the framework of a relatively small workshop (cf., for instance, a big forthcoming program at CRM Montreal on probabilistic models in physics). Instead we concentrated on the following 3 areas mostly related to discrete structural probability, and which are currently in the process of an active development and mutual interaction

- Random walks
- Percolation on groups and graphs
- Random groups

The total of 30 one-hour research talks were presented during the 2 weeks of the program. They were scheduled (usually 3 talks a day) in such a way that the participants had enough time for informal discussions and for work in smaller groups. Among these talks were the following:

Wolfgang Woess (Graz): On the spectrum of lamplighter groups and percolation clusters.

Let G be a finitely generated group and X its Cayley graph with respect to a finite, symmetric generating set. Furthermore, let H be a finite group, and consider the lamplighter group (wreath product) over G with group of "lamps" H. The author (jointly with F. Lehner) showed that the spectral measure (Plancherel measure) of any symmetric "switch-walk-switch" random walk on the wreath product coincides with the expected spectral measure (integrated density of states) of the random walk with absorbing boundary on the cluster of the group identity for Bernoulli site percolation on X with parameter $p = 1/|H|$. In particular, if the clusters of percolation with parameter p are almost surely finite then the spectrum of the lamplighter group is pure point. This generalizes results of Grigorchuk and Zuk, resp. Dicks and Schick regarding the case when G is infinite cyclic.

Tullio Ceccherini-Silberstein (Benevento) and Michel Coornaert (Strasbourg): Cellular automata and surjunctivity, I and II.

A map from a set into itself is called surjunctive if it is surjective or not injective. The goal of these two talks was to present recent results on the surjunctivity of cellular automata on shift spaces.

Mikhail Gordin (St.Petersburg): Baker sequences and multiparameter martingale approximation.

Baker sequences appeared in a problem in the metric number theory posed to W. Philipp by R. C. Baker. To get such a sequence, one needs to take a multiplicative semigroup of naturals generated by a finite set of coprime numbers and arrange its elements according to their magnitude. Uniform distribution and other related problems associated with Baker sequences were studied by several authors. The talk (based in part on a joint paper with M. Weber) dealt with the question about how such problems can be treated by means of the (multiparameter) martingale approximation.

Matthias Keller (Jena): The Laplacian on rapidly branching graphs

The author discussed the unbounded Laplace Operator on graphs with uniformly increasing vertex degree and gave a characterization for absence of essential spectra. In particular he presented this characterization for planar tessellations in terms of the combinatorial curvature.

Christophe Pittet (Marseille): Spectral distribution of Laplace operators on infinite groups.

There is a simple formula for computing the spectral distribution of Laplace operators (in degree 0) on finitely generated groups. This relies on the large-scale isospectral profile of the group.

Florian Sobieczky (Graz): (Non-)Amenability of horospheric products of trees with uniform growth.

It has been shown that horospheric products of random trees (such as Galton-Watson trees) are almost surely amenable, if the condition of equal asymptotic growth is met. While the role taken by randomness for the stability of amenability under deviations of equal growth had also been clarified to some extent, the question of this stability remained completely open for deterministic trees with aperiodic order, which represent an intermediate case between randomly and periodically changing trees: In the present approach (joint work with D. Lenz and I. Veselic), it is shown that for uniformly growing trees with an aperiodic function on the integers dictating the degree of all vertices on each horosphere, the equal-growth-condition is necessary and sufficient for the amenability of the horospheric product.

Michael Keane (Middletown): The recurrence-transience dichotomy for once reinforced random walks.

After reviewing the classical dichotomy for simple random walk on countable locally finite connected graphs, the speaker considered once reinforced random walks with fixed reinforcement parameter on these graphs. It is still an open question whether the classical dichotomy remains valid in this situation, even for some simple examples. However, it is possible to establish part of the result, which was explained in this lecture. At the end of the lecture, the current state of affairs concerning the question of recurrence or transience for once reinforced random walks on ladders and in two-dimensional discrete space was reviewed.

Neil O'Connell (University of Warwick): Exponential functionals of Brownian motion and class one Whittaker functions.

The talk (based on a joint work with F. Baudoin) was devoted to a new link between classical problems of mathematical physics and probability. Consider exponential functionals of a multi-dimensional Brownian motion with drift, defined via a collection of linear functionals. One can give a characterisation of the Laplace transform of their joint law as the unique bounded solution, up to a constant factor, to a Schrödinger-type partial differential equation. One can further characterise all diffusions which can be interpreted as having the law of the Brownian motion with drift conditioned on the law of its exponential functionals. In the case where the family of linear functionals is a set of simple roots, the Laplace transform of the joint law of the corresponding exponential functionals can be expressed in terms of a class one Whittaker function associated with the corresponding root system. In this setting, some basic properties of the corresponding diffusions (Whittaker processes) are established.

Michele D'Adderio (San Diego): On isoperimetric profiles of algebras.

Isoperimetric profile in algebras was first introduced by Gromov. In this talk the behavior of the isoperimetric profile under various ring theoretic constructions and its relation with Gelfand-Kirillov dimension and amenability were investigated.

Anders Karlsson (Stockholm): Asymptotics of the number of spanning trees in discrete tori and heights of real tori.

The asymptotics of spectral invariants for sequences of Cayley graphs of finite abelian groups when the orders of the cyclic factors tend to infinity at comparable rates were studied. An asymptotic expansion of the determinant of the combinatorial Laplacian, which by a classical theorem relates to the number of spanning trees, is established. This extends works of physicists and mathematicians, in particular an asymptotic formula of Duplantier-David in dimension 2. The zeta-regularized determinant of the Laplacian of a limiting real torus appears as a constant in this expansion. The heat kernel analysis which is basic to this approach involves in particular I-Bessel functions. (Joint work with G. Chinta and J. Jorgenson.)

Michael Bjorklund (Stockholm): Percolation and higher rank subadditive ergodic theory.

The asymptotic shape theorem by Cox-Durrett (and later developed by Boivin to ergodic actions) roughly asserts that the shape of large balls in $\mathbb{Z}^d$ equipped with a random inner semimetric (equivariant with respect to an ergodic action of $\mathbb{Z}^d$) behaves non-randomly. In one dimension, this theorem essentially reduces to Birkhoff's theorem (because of the interior assumption on the semimetrics). In this talk an extension of the asymptotic shape theorem in $\mathbb{Z}^d$ which does not assume that the semimetrics are inner was discussed (in particular, in dimension 1 this is the classical Kingman subadditive ergodic theorem).

Jean-Pierre Conze (Rennes): The CLT for sequences of matrices in $SL(d, \mathbb{Z}^+)$ and a quenched CLT

In this joint work with Stéphane Le Borgne and Mikael Roger, the "sequential dynamical system" obtained by composing a sequence (τ_n) of toral automorphisms with $\tau_n x = Ax \bmod \mathbb{Z}$ or $\tau_n x = Bx \bmod \mathbb{Z}$, where A and B are two matrices in $SL(d, \mathbb{Z})$, was considered. We give conditions which imply decorrelation and enable to apply a method of "multiplicative systems" developed by Komlòs, providing a Central Limit Theorem for the sums $\sum_{k=1}^{n} f(\tau_k \circ \tau_{k-1} \cdots \circ \tau_1 x)$ for regular functions f on $\mathbb{T}^d$ were given. These conditions can be checked, for example, for 2×2 matrices with positive coefficients. In dimension d, they can be applied as well to a product of independent automorphisms $A_n(\omega) \in \{A, B\}$, with A and B in $SL(d, \mathbb{Z}^+)$ in order to prove a "quenched" CLT (i.e almost sure with respect to ω), a question which was also considered recently by Ayyer, Liverani and Stenlund.

Philippe Biane (Paris): Continuous Crystal, Coxeter group and Brownian motion.

This is a joint work with Philippe Biane and Neil O'Connell. One can define a continuous analogue of a Kashiwara Crystal for any finite Coxeter group. The associated Duistermaat Heckman measure is a conditional law of the Brownian motion.

Balint Virag (Toronto): Amenability of linear rate automata groups.

Automata groups are the algebraic facet of fractals. The emerging unified theory of automata groups starts with their classification by their rate – it is either polynomial of degree d or exponential. Sidki showed that polynomial rate automata groups have no free subgroups, and asked whether all these groups are amenable. Bartholdi, Nekrashevich and Kaimanovich (2008) showed this for the bounded ($d = 0$) case. In this talk about joint work with G. Amir and O. Angel, it was shown that linear ($d = 1$) rate automata groups are amenable, and explained why the method of proof may break down for high degree d.

Invited Scientists: Fernando Alcalde, Wlodzimierz Bak, Philippe Biane, Michael Björklund, Philippe Bourgerol, Theo Buehler, Jan Cannizzo, Tullio Ceccherini-Silberstein, Jean-Pierre Conze, Michel Coornaert, Michele D'Adderio, Bertrand Deroin, Anna Erschler, Gennadiy Feldman, Mikhail Gordin, Yves Guivarc'h, Vadim Kaimanovich, Anders Karlsson, Mike Keane, Matthias Keller, Victor Kleptsyn, Yves Le Jan, Bunrith Jacques Lim, Keivan Mallahi-Karai, Tatiana Nagnibeda, Neil O'Connell, Valery Oseledets, Maria Perez, Dimitri Petritis, Christophe Pittet, Tal Poznansky, Klaus Schmidt, Nikita Selinger, Richard Sharp, Florian Sobieczky, Gerhard Racher, Balint Toth, Evgeny Verbitskiy, Anatoly Vershik, Wolfgang Woess, Maciej Wojtkowski

5th Vienna Central European Seminar on Particle Physics and Quantum Field Theory: "Highlights in Computational Quantum Field Theory"

Organizer: H. Hüffel (University of Vienna). Advisory Board: Stefan Dittmaier (Munich), Dietmar Kuhn (Innsbruck), Christian Lang (Graz), Harald Markum (Vienna)

Dates: November 28 - 30, 2008

Budget: ESI €2.700,–. Also supported by the Austrian Federal Ministry for Science and Research, by the Institute for High Energy Physics of the Austrian Academy of Sciences, by the Faculty of Physics (University of Vienna) and by the Vienna Convention Bureau.

Report on the programme

The "Vienna Central European Seminar on Particle Physics and Quantum Field Theory" is meant to be a platform for junior scientists, as well as a unique forum for coordinating conferences, schools and doctoral courses in the Central European Region.

This year, "Highlights in Computational Quantum Field Theory" was the chosen subject. The present status of the Monte Carlo event generation for collider experiments and the GRID technology were presented. In perturbative quantum field theory the automation of loop and precision calculations were covered, at the nonperturbative level advances in lattice QCD as well as simulations of M-theory, supergravity and black holes.

Invited talks:

Konstantinos Anagnostopoulos (Athens): "Probing Non-Perturbative String Dynamics Using Monte Carlo Simulations"

Michael Creutz (Brookhaven): "Minimally doubled chiral fermions

Philippe de Forcrand (Zurich): "QCD at finite temperature and density in the strong coupling limit

Christof Gattringer (Graz) : "QCD Phase Transition and Fermionic Boundary Conditions

Nigel Glover (Durham): "Perturbative QCD for the LHC"

Dieter Kranzlüller (Munich): "GRIDS in Europe - A Computing Infrastructure for Science"

Thomas Lippert (Jülich): "Advancements in Simulations of Lattice Quantum Chromodynamics"

Owe Philipsen (Münster): "Exploring the QCD phase diagramm on the lattice"

Michael Seymour (CERN): “Monte Carlo simulation of collisions at the LHC”
Jos Vermaseren (Amsterdam): “Some algebraic methods in Field Theory”
Public Lecture:
Michael Creutz (Brookhaven): “Quarks, Gluons And Lattices”

Supersymmetry and Noncommutative QFT: In Memoriam Julius Wess

Organizers: H. Grosse (Vienna), P. Schupp (Bremen)

Dates: December 4 - 6, 2008

Budget: ESI €5.351,78, EU-Project €1.200,–, City of Vienna €1.000,–

Report on the programme

Julius Wess was one of the most famous Austrian Physicist of the last decades. In 1974 he, together with Bruno Zumino, “invented” space-time supersymmetry that led to the prediction of the existence of new elementary particles, presently looked for at LHC at CERN. After his move from Karlsruhe to Munich in 1989 Julius Wess changed his main research subject to quantum field theory over noncommutative spaces. The choice of topics for the workshop reflected his manifold research interests.

The talks centered around the following subjects:

- Noncommutative Gravity and Supergravity
- Quantization methods
- Emerging Space-Time and Gravity
- Fuzzy Systems and Geometry
- Phenomenology
- Renormalizability
- Strings and fundamental symmetry

1. Deformed Gravity

Over more than 15 years Julius Wess worked on the applications of noncommutative geometry to physical models. Paolo Aschieri reviewed these developments, which finally led to the formulation of deformed Einstein gravity (as presented by Dimitrijevic and Peter Schupp). Deformation by twists is the main starting point, it leads to problems like Noether symmetry, variational problems and supergravity extentions (Castellani).

2. Quantization

After the boom in deformed quantum physics the old questions of deformation quantization became again popular. In addition the general classification of deformations of symplectic manifolds of Kontsevitch led to many insights. Schlichenmaier reviewed the Berezin-Toeplitz quantization procedure and Gieres gave simple but interesting examples of deformations in quantum mechanical models with magnetic fields.

3. Emerging Space-Time

Gauge models and gravity models on noncommutative spaces are intimately connected. These models generate their geometry through ground state configurations. Space-Time emerges and leads to interesting new aspects (Steinacker, Presnajder). The hidden Groupoid Symmetry behind Einstein gravity is a new development resulting from a work of Weinstein with Blohmann, reviewed by the later.

4. Fuzzy Physics

Noncommutative spaces can be used as regularization: The hope to regularize the classical singular solutions of Einstein gravity like the Schwarzschild solution is not yet fulfilled. These attempts were presented by Madore. A number of examples of Fuzzy systems and the change of geometry connected to a change of the ground state structure was studied in Dublin around O'Connor. A connection to spin models and their phase transition structure leads to very promising (mostly numerically) results.

5. Phenomenology

Julius Wess was always interested in connecting the abstract developments to physics. He was already involved in extracting new processes which might hint towards a deformed space-time. These developments are pushed forward by Trampetic and co-workers.
Interesting model building can be obtained by putting Fuzzy extra dimensions. The resulting models are renormalizable (Zoupanos).

6. Renormalization

should act as a guiding principle to select sensible models. Gauge theories are not yet well understood in that respect. Wohlgenannt and Grosse reviewed the present status. An absolute highlight in this area was presented by Buric: During her last visit at ESI she started a calculation of a differential calculus for a truncated algebra approximating Moyal spaces. It turned out to lead to a space with curvature reproducing the oscillator potential used to renormalize scalar field theory. This promising issue was discussed intensively between participants during and after the Workshop. Certain problems can be avoided if one expands in the deformation parameter as it was reported by Jonke.

7. Strings

Several contributions were devoted to the connection between the two main research areas of Julius Wess. The particular problem of dimensional reduction of strings leading to a variety of possible models was presented by Chatzistarakidis. An impressive overview over symmetries and dualities behind string models was given be Nicolai. The group $E10$ seems to be suitable to put order into the large number of possible models.

Invited Scientists: Paolo Aschieri, Christian Blohmann, Maja Buric, Leonardo Castellani, Athanasios Chatzistavrakidis, Marija Dimitrijevic, Francois Gieres, Harald Grosse, Larisa Jonke, John Madore, Hermann Nicolai, Denjoe O'Connor, Petr Presnajder, Alexander Schenkel, Martin Schlichenmaier, Peter Schupp, Harold Steinacker, Josip Trampetic, Zhituo Wang, Michael Wohlgenannt, George Zoupanos

Profinite Groups

Organizers: K.Auniger(Vienna), F. Grunewald (Düsseldorf), W. Herfort (Vienna), P. Zalesskii (Brasilia)

Dates: December 7 - 20, 2008

Budget: ESI €19.002,44, Fak. Mat. Univ. Vienna €7000,–

Report on the programme

During the first week the workshop was organized as a meeting of specialists in the area with 26 talks connected to topics listed below. The titles can be found under

`http://www.math.tuwien.ac.at/~herfort/ESI_08/VORTRAEGE/schedule.php`

The first week then ended with a problem session on Friday and led to the followig list of problems:

`http://www.math.tuwien.ac.at/~herfort/ESI_08/PROBLEMS/problems.pdf`

During the second week 6 further talks took place and the focus was on a discussion of problems from the session. Research and discussion concentrated mainly around the following topics:

1. The congruence subgroup problem
2. Combinatorial pro-p group theory
3. (Co)homological methods
4. Just infinite groups

1. The congruence subgroup problem

A connection between the Congruence Subgroup Problem (for short CSP) and combinatorial theory of profinite groups often arised in the duscussion during the conference and the workshop. It arised in a comment of J.-P. Serre during the talk of Karl Lorensen and subsequent discussion between him and Alex Lubotzky. The connection was stressed by A. Rapinchuk when he formulated the following problem during the problem session.

An abstract (discrete) group G is said to have *bounded generation* (BG) if there exist $\gamma_1, \dots, \gamma_d \in G$ (not necessarily distinct) such that

$$G = \langle \gamma_1 \rangle \cdots \langle \gamma_d \rangle$$

where $\langle \gamma_i \rangle$ is the cyclic group generated by γ_i. Similarly, a profinite group G has (BG) as a profinite group if there are $\gamma_1, \dots, \gamma_d \in G$ such that

$$G = \overline{\langle \gamma_1 \rangle} \cdots \overline{\langle \gamma_d \rangle}$$

where $\overline{\langle \gamma_i \rangle}$ is the closure of the cyclic subgroup generated by γ_i.

Let $G = G_1 \star_{G_0} G_2$ be an amalgamated free product. There are two interrelated problems:

(1) Give (verifiable) *sufficient* conditions for G to have (BG);

(2) Give *sufficient* conditions for the profinite completion $\widehat{G}$ to have (BG) as a profinite group.

There are *necessary* conditions (Grigorchuk, Fujiwara) in the situation described in (1): if for at least one $i = 1, 2$ the number of double cosets $G_0 \backslash G_i / G_0$ is $\geqslant 3$ then G does not have (BG) (this is established by showing that the second bounded cohomology of G is infinite dimensional, i.e. by constructing infinitely many linearly independent functions $\chi\colon G \to \mathbb{C}$ satisfying

$$|\chi(gh) - \chi(g) - \chi(h)| \leqslant C \quad \text{for some constant} \quad C = C(\chi) \quad \forall g, h \in G$$

and $\chi(g^n) = n\chi(g)$ for all $g \in G$ and $n \in \mathbb{Z}$).

No nontrivial necessary conditions are known for the profinite version (2).

The interest in questions (1) and (2) is stimulated by the fact that according to the Bass-Serre theory, many S-arithmetic subgroups of algebraic groups $\mathrm{SL}_{1,D}$ associated with quaternion algebras are amalgamated free products, and any progress on questions (1) and (2) would be instrumental in analyzing the congruence subgroup property for these groups which is a widely open question.

During the workshop Andrei Rapinchuk gave a very interesting talk presenting his new result obtained jointly with Gopal Prasad on the congruence kernel being almost 1-generated as a normal subgroup of the arithmetic completion of an absolutely simple simply connected algebraic group G defined over a global field K.

A discussion of the variation of the CSP that had been formulated by Ihara for the automorphism group of a free group of finite rank took place. This question has connections with the talks of Marco Boggi and Pierre Lochak and was discussed also by Fritz Grunewald, Alex Lubotzky, Andrei Rapinchuk and Pavel Zalesskii. In the paper of Asada the answer has been claimed to be 'yes' for the case of rank 2, but it is open for other ranks.

2. Combinatorial theory of pro-p groups

Alex Lubotzky gave a talk on discrete and profinite presentations of finite simple groups. In response to conjectures of Babai and Szemeredi on the one hand (motivated by questions in computational group theory) and of Mann on the other hand (motivated by questions on subgroup growth) he, jointly with Bob Guralnick, Bill Kantor and Martin Kassabov, showed that all non-abelian finite simple groups (with the possible exception of Ree groups) have presentations which are small (bounded number of relations) and short (w.r.t the length of the relations). This is very surprising as the simple abelian groups – the cyclic groups of prime order – do not have such presentations! He described the motivations and results, a cohomological application (proving a conjecture of Holt) and some connections with discrete subgroups of Lie groups. He also discussed the connection with profinite presentations.

One theme of the workshop that raised much discussion was a new class of pro-p groups introduced during the talk of Dessislava Kochloukova. The groups are the pro-p analogue of limit groups that had been extensively studied during last decades and play a key role in the solution of the famous Tarski problem. In addition to the list of open questions that Kochloukova presented, Thomas Weigel asked whether a pro-p Poincare duality group of dimension 3 can be a limit pro-p group. The question was answered negatively during the workshop.

Lior Bary-Soroker during his talk introduced the notion of projective pairs of profinite groups. The main question is to find a good characterization of projective pairs. In the workshop itself there were some advances toward this problem by the group: Pavel Zalesskii, Thomas Weigel, Chen Meiri, and myself. We managed to give several characterizations in some easier categories, e.g., pro-p groups and pro-nilpotent groups.

3. (Co)homological methods

Profinite (co)homology is a tool for studying the possible structure of certain profinite Galois groups. Progress has been made in describing mainly profinite groups of low cohomological dimension.

Very interesting results due to Fritz Grunewald, Andrei Jaikin, Aline Pinto and P.A. Zalesskii were described in the talk of Aline Pinto about the cohomology of profinite groups of non-positive deficiency. The existence of a finitely generated normal subgroup in such a group gives rather strong consequences for the (cohomological) structure of the group. One of them is that cohomological goodness (as has been introduced by J.-P. Serre in his book on Galois Cohomology) of ascending HNN-extension of free groups can be deduced by using the results described by Karl Lorensen in his talk. Other results on the cohomology of pro-p groups were given in the talk of Ido Efrat and these are related to Galois theory.

4. Just infinite groups

John S. Wilson has informed us that after the conference he was able to answer a question raised in one of the lectures, by constructing many examples of hereditarily just infinite groups that are not virtually pro-p. (HJI simply means that all subgroups of finite index are just infinite.)

Invited Scientists: Miklos Abert, Menny Aka, Jorge Almeida, Karl Auinger, Yiftach Barnea, Lior Bary-Soroker, Gunther Bergauer, Marco Boggi, Nigel Boston, Zoe Chatzidakis, Ido Efrat, Liad Fireman, Fritz Grunewald, Dan Haran, Wolfgang Herfort, Moshe Jarden, Otto H. Kegel, Helmut Koch, Dessislava Kochloukova, Jochen Königsmann, Pierre Lochak, Karl Lorensen, Alex Lubotzky, Andrea Lucchini, Avinoam Mann, Chen Meiri, Primoz Moravec, Aline Pinto, Peter Plaumann, Andrei Rapinchuk, Luis Ribes, Liudmila Sabinina, Dan Segal, Jean Pierre Serre, Aner Shalev, Pavel Shumyatsky, Peter Symonds, Thomas Weigel, John Wilson, Reinhard Winkler, Pavel Zalesskii, Flavia Zapata, Theo Zapata, Efim Zelmanov, Andrzej Zuk

Junior Research Fellows Programme

Established in 2004 and funded by the Austrian government, the Junior Research Fellows Programme provides support for PhD students and young post-docs to participate in the scientific activities of the Institute and to collaborate with its visitors and members of the local scientific community.

Due to its international reputation and to its membership in the European Post-Doc Institute the ESI received many applications from highly qualified post-docs for funding of extended visits (ranging from two to six months) only some of which could be covered by the Junior Fellows Programme. In view of the close and well-established links between the ESI and many leading Eastern European academic institutions this programme was particularly beneficial to young researchers from Eastern Europe and Russia. The presence of the Junior Research Fellows contributed significantly to the positive and dynamic atmosphere at the ESI.

The figures for the two regular rounds of applications in 2008 were as follows:

1st deadline: 11.04.2008
Number of applications: 34
Number of accepted applicants: 10
Number of months granted: 16 for 2008, 12 for 2009

2nd deadline: 14.11.2008
Number of applications: 36
Number of accepted applicants: 9
Number of months granted: 34 for 2009

Junior Research Fellowships in 2008

Name	Gender	Duration	Nationality
Hendrik Adorf	male	05/06 - 22/09	Germany
Vasiliki Anagnostopoulou	female	04/02 - 30/04	Greece
Caterina Cusulin	female	01/06 - 30/09	Italy
Philipp Geiger	male	01/05 - 31/10	Austria
Neven Grbac	male	25/05 - 25/07	Croatia
Harald Grobner	male	01/01 - 30/06	Austria
Minh Ha Quang	male	01/01 - 31/03	Vietnam
Eman Hamza	female	04/02 - 31/07	Egypt
Matthieu Josuat-Verges	male	15/05 - 15/07	France
Peggy Kao	female	21/07 - 21/10	Australia
Aleksey Kostenko	male	03/07 - 30/09	Ukraine
Christian Lübbe	male	01/01 - 31/03	Germany
Mate Matolcsi	male	01/02 - 31/03	Hungary
Philippe Nadeau	male	01/04 - 30/06	France
Maryna Nesterenko	female	01/10 - 30/11	Ukraine
Radu Saghin	male	27/05 - 23/08	Romania
Maria Schimpf	female	01/01 - 31/03	Austria
Josef Silhan	male	04/09 - 31/12	Czech Republic
Rafal Suszek	male	29/08 - 09/11	Poland
Balint Vetö	male	01/02 - 30/06	Hungary
Le Anh Vinh	male	15/02 - 15/08	Vietnam
Mihaly Weiner	male	12/08 - 12/10	Hungary
Lenka Zalabova	female	01/08 - 31/12	Czech Republic

Preprints contributed: [2018], [2022], [2025], [2038], [2039], [2040], [2041], [2042], [2043], [2044], [2057], [2081], [2082]

Senior Research Fellows Programme

To stimulate the interaction with the local scientific community the ESI offers lecture courses on an advanced graduate level. These courses are taught by Senior Research Fellows of the ESI whose stays in Vienna are financed by the Austrian Ministry of Education, Science and Culture and the University of Vienna. This programme also includes long-term research stays of small groups or individual distinguished researchers. The coordinator of this programme was Joachim Schwermer.

This year's programme concentrated on the following lecture courses:

Christos N. Likos (Universität Düsseldorf), Winter 2007/08: *Introduction to Theoretical Soft Matter Physics*

Radoslav Rashkov (Sofia University), Winter 2007/08: *Dualities between gauge theories and strings*

Goran Muić (University of Zagreb), Winter 2008/09: *Selected Topics in the Theory of Automorphic Forms for Reductive Groups*

Herbert Kurke (Humboldt Universität Berlin), **Denis Osipov** (Steklov Mathematical Institute, Moscow), **Alexander Zheglov** (Moscow State University), January 7 - February 2, 2008

Werner Ballmann (Universität Bonn), May 4 - 31, 2008

Roberto Longo (Universitá di Roma "Tor Vergata"), August 20 - December 15, 2008

Christos N. Likos: Introduction to Theoretical Soft Matter Physics

Course: In this course, we first presented a general introduction to the systems that are broadly classified under the term "Soft Matter". These encompass colloids of various shapes, polymers of a very large variety of architectures, micelles, rods, membranes, polyelectrolytes etc. We emphasized that the common characteristic of all these lies in the occurrence of *mesoscopic structural length scales* in the problem, associated with the fact that soft matter consists of mesoscopic entities dissolved in a microscopic solvent.

To deal with the complicated statistical-mechanical problem, we rigorously derived the strategy of *coarse-graining*, introducing thereby the concept of effective interactions. We showed how spontaneous, correlated dipole-dipole fluctuations lead to the ubiquitous van der Waals, or dispersion, attractions between colloids. Thereby, we introduced charge- and steric stabilization as means to overcome the attractions.

We further discussed in some details some basic notions from polymer physics, starting from the random walk and proceeding to its self-avoiding version, which model the statistics of real chains in a good solvent. Afterward, we went into quite some detail into the theory of structure and thermodynamics of classical liquids and liquid mixtures, including the theory of liquid-gas phase transition and of crystallization.

At the last part of the course, we discussed in depth the principles and applications of Density Functional Theory (DFT), which allows for a unified treatment of the properties of both homogeneous and inhomogeneous fluids and their mixtures. After spending a few lectures to thoroughly understand the mathematical uniqueness and minimization theorems of the free energy functional, we derived specific, accurate functionals to analyze: demixing transitions; the calculation of the free interfaces; and wetting. In a specific application, we also applied DFT to understand various scenarios of cluster formation that are in soft matter systems. We also briefly discussed computer simulation techniques.

The course was attended throughout the semester by 6 to 15 participants, most of them being Graduate students at the University of Vienna or the Vienna University of Technology. Each student submitted a short research report in lieu of regular exercises, which would have been rather inappropriate for a research-oriented course.

Research: My main research partner in Vienna has been Prof. Dr. Gerhard Kahl from the TU Wien, with whom we have carried on our collaboration on a number of topics. Mainly, we focused on the further development and application of genetic algorithms, which resulted in one paper already accepted for publication (submitted in the preprint server), as well as one more coming up. We have carried out extended and detailed research on work to-date on GAs, with the goals of (a) writing together a review article (in preparation) and refining the technique to meet the needs of soft matter research. In addition, we put the finishing touches on work that preceded my stat at ESI, and which has just appeared in print [Physical Review Letters 100, 028301 (2008).] Further contacts were established with Prof. Dr. Christoph Dellago from the University of Vienna, pertaining to the study of nucleation in cluster-forming systems.

I continued and completed work on the effective forces between polyelectrolyte-grafted colloids, in collaboration with Prof. Dr. Friedrich Kremer (Leipzig), submitted as preprint at the ESI-server and being currently under consideration in Physical Review Letters.

Visitors from my group in Düsseldorf and external collaborators: Dr. Federica Lo Verso contributed both to work on genetic algorithms and to independent work on end-functionalized polymers (ESI-preprint [1944]). Tobias Tückmantel established important contacts with the Kahl-group and will be visiting them in May, 2008. Sven van Teeffelen and Oliver Jansen had some very fruitful exchanges with the Dellago group. Dr. Emanuela Zaccarelli and Dr. Christian Mayer visited to complete work on glassy soft mixtures (ESI preprint [1997]) and established contacts with the Kahl group. Finally, Dr. Ronald Blaak, Dr. Aaron Wynveen and Sebastian Huißmann, all members of the Düsseldorf group, visited the ESI to keep up on common work.

Preprints contributed: [1994], [1995], [1996], [1997]

Radoslav Rashkov: Dualities between gauge theories and strings

First I would like to thank ESI for the appointment as an Senior Research Fellow (October 01-January 31), which gave me the opportunity to do productive research enhancing my expertise and in the same time to enjoy the unique atmosphere of the city of Vienna.

Course: The idea about the correspondence (duality) between the large N limit of gauge theories and string theory has been developed over the years in many directions. Recently the research in this area became topical in view of expected new experimental results from LHC (CERN). The lectures were based on recent advances on both, the string and the gauge theory sides of the conjectured duality. The aim was to describe the physical ideas and provide mathematical tools to attack the challenges arising in this fascinating area.

The course was divided in four parts. In the first part of the lectures I gave a brief review of (super) string theory. This included the notion of worldsheet symmetries and 2d (super) conformal field theories. Here I recalled basic facts about vertex operators and representations of infinite dimensional algebras.

The next part of the lectures contained the notion of supersymmetry algebra, $\mathcal{N} = 4$ superconformal algebra in four dimensions and their representations. In this part I discussed the properties of $\mathcal{N} = 4$ Supersymmetric Yang-Mills (SYM) theory as well as its derivation from $\mathcal{N} =$ SYM in 10d.

Part III of the lectures dealt with the low-energy limit of string theory and its effective target space action. In this part I discussed in some length D-branes and their dynamics as well as dualities between various string theories. Based on the properties of the branes and the effective geometries accounting for the backreaction, I formulated and discussed the Maldacena conjecture and elaborated on examples demonstrating how the conjectured duality works.

The last part of the lectures dealt with the most recent developments in the area. Many papers have indicated that type IIB string theory on $AdS_5 \times S^5$ and $\mathcal{N} = 4$ super-Yang-Mills (SYM) theory in four dimensions may be integrable in the planar limit (and maybe beyond). The techniques of integrable systems have thus become useful in studying the AdS/CFT correspondence in details. In this part I gave examples of various reductions of the string theory to integrable models. I discussed the integrability of the theory from various points of view using different techniques: reduction to Neumann (Neumann-Rosochatius) model, Pohlmeyer reduction, approximation with certain spin chain models, how one can solve these models by making use of Bethe ansatz. The subsequent discussion of the application of Backlund transformations/dressing method, local and non-local currents/charges etc. was based on the most recent developments in the area.

Although intensive and covering wide range of problems, I enjoyed very much giving this course.

Research:

During my stay at ESI I attended several activities related, or pretty close, to my research interests. The discussions with the participants will certainly have an impact on my future research. These are: ESI workshop "Noncommutative Quantum Field Theory", EU Network in Noncommutative Geometry, Workshop "Renormalization group flow and Ricci flow". My stay at ESI was particularly valuable giving me the opportunity to start new projects and continue my collaboration with Prof. M. Kreuzer and his group. Moreover, I enjoyed the fruitful discussions with Prof. Harald Grosse.

I published my research results at ESI in the following preprints: "A Note on the Near Flat Limit for Strings in the Maldacena-Nunez Background", ESI-1983 (with M. Kreuzer and C. Mayrhofer); "Non-Topological Non-Commutativity in String Theory", ESI-1992 (with Sebastian Guttenberg, Manfred Herbst and Maximilian Kreuzer); "On the Anatomy of Multi-Spin Magnon and Single Spike String Solutions", ESI-1993.

The new projects I started at ESI are: on integrable structures of superstring theory in diverse backgrounds and their relations to gauge theories; integrable limits of string theory in non-trivial backgrounds; phenomenological consequences of marginally deformed gauge theories and their string duals; Seiberg-Witten map and effective actions for non-constant B-field.

I highly appreciate the grant provided by the Senior Fellowship Programme to invite visiting researchers in support of on-going and future research projects. The scientists I had invited for this period are Dr. Manfred Herbst, Dr. Hristo Dimov and Prof. Ralph Blumenhagen.

Preprints contributed: [1983], [1992], [1993]

Goran Muić: Selected Topics in the Theory of Automorphic Forms for Reductive Groups

Course: Selected Topics in the Theory of Automorphic Forms for Reductive Groups

The course was devoted to the study of square integrable automorphic forms for a semisimple algebraic group G over a number field k. The square integrable automorphic forms are defined in the style of Harish–Chandra who emphasizes their role in the spectral decomposition of the corresponding L^2 space $L^2(G(k)\backslash G(\mathbb{A}))$ where $\mathbb{A}$ is a ring of adeles of k. We discussed the relation to the corresponding space $L^2(\Gamma\backslash G_\infty)$ of square–integrable functions on $\Gamma\backslash G_\infty$, where

G_∞ is the group of $\mathbb{R}$–points of a $\mathbb{Q}$–group $Res_{k/\mathbb{Q}}$ obtained by restriction of scalars and Γ is a congruence subgroup of G_∞. Special attention was given to the question regarding existence and construction of cuspidal automorphic forms which are the most important example of square integrable automorphic forms.

We covered the following subjects:

- Basic notions in the analysis on $G(\mathbb{A})$: measures, the decomposition of the measures into local components, the notion of the measure on $G(k)\backslash G(\mathbb{A})$, the notion of C^∞ functions on $G(\mathbb{A})$.
- The relation between open–compact subgroups of the group of finite adeles $G(\mathbb{A}_f)$ and congruence subgroups of G_∞.
- Basic notions in the theory of unitary representations of locally compact groups with applications to the right regular representations $L^2(\Gamma\backslash G_\infty)$ and $L^2(G(k)\backslash G(\mathbb{A}))$.
- A discussion of the $(\mathfrak{g}_\infty, K_\infty)$–module associated to an irreducible subrepresentation of $L^2(\Gamma\backslash G_\infty)$ and the notion of the space of all square–integrable automorphic forms $\mathcal{A}^2(\Gamma\backslash G_\infty)$. The decomposition of $\mathcal{A}^2(\Gamma\backslash G_\infty)$ into irreducible $(\mathfrak{g}_\infty, K_\infty)$–modules and the relation to the decomposition of the discrete part of $L^2(\Gamma\backslash G_\infty)$ into irreducible representations. Two fundamental results of Harish–Chandra. The analogous notion and results in the adelic setting $\mathcal{A}^2(G(k)\backslash G(\mathbb{A}))$.
- The notion of a cuspidal automorphic form and fundamental results concerning the decomposition of the corresponding spaces $\mathcal{A}_{\text{cusp}}(\Gamma\backslash G_\infty)$, $L^2_{\text{cusp}}(\Gamma\backslash G_\infty)$, $\mathcal{A}_{\text{cusp}}(G(k)\backslash G(\mathbb{A}))$, and $L^2_{\text{cusp}}(G(k)\backslash G(\mathbb{A}))$.
- The construction of cusp forms via L^1–Poincaré series in the case that G_∞ has the same rank as one of its maximal compact subgroup K_∞.
- The question of existence of cusp forms in $L^2_{\text{cusp}}(\Gamma\backslash G_\infty)$ using compactly supported Poincaré series.

Research: The wonderfully stimulating environment of the Erwin Schrödinger Institute gave me the opportunity to write three papers related to the areas of my lecture course. I studied cuspidal automorphic forms for a semisimple algebraic group G over a number field k in the adelic setting $\mathcal{A}_{\text{cusp}}(G(k)\backslash G(\mathbb{A}))$ and in the classical setting $\mathcal{A}_{\text{cusp}}(\Gamma\backslash G_\infty)$ where G_∞ is the group of $\mathbb{R}$–points of a $\mathbb{Q}$–group $Res_{k/\mathbb{Q}}$ obtained by restriction of scalars and Γ is a congruence subgroup of G_∞. I was working out two major papers on the existence of cusp forms for general semisimple groups G over a number field k. In more detail, in the paper *"On the decomposition of $L^2(\Gamma\backslash G)$ in the cocompact case"* [2120] I discuss the existence of various irreducible subrepresentations of $L^2(\Gamma\backslash G_\infty)$ when G_∞ is an arbitrary semisimple Lie group which is not compact, and Γ is its arbitrary cocompact discrete subgroup. The approach is based on our idea of a spectral decomposition for compactly supported Poincaré series. We explain the relation to the work of Vogan on minimal K–types. Also, we show how to realize non–spherical principal series for $SL_2(\mathbb{R})$ as subrepresentations of $L^2(\Gamma\backslash SL_2(\mathbb{R}))$,

In the sequel to the paper *"On the decomposition of $L^2(\Gamma\backslash G)$ in the cocompact case"* called *"Spectral Decomposition of Compactly Supported Poincaré Series and Existence of Cusp Forms"* [2119], we consider the non–compact case with Γ a congruence subgroup of G. Again, we apply our idea of a spectral decomposition for compactly supported Poincaré series. But this time the situation is more complicated due to non–compactness of $\Gamma\backslash G$. The problems are caused by the presence of Eisenstein series. In order to avoid Eisenstein series we construct compactly supported Poincaré series which are cuspidal. The method is based on an application of Hecke operators and Bernstein's decomposition of the category of smooth representations of p–adic groups.

The third paper in this series *On the cusp forms for the congruence subgroups of* $SL_2(\mathbb{R})$ (ESI Preprint [2121]) gives an application of the paper *"Spectral Decomposition of Compactly Supported Poincaré Series and Existence of Cusp Forms"* to study Maass forms for $SL_2(\mathbb{R})$. We show how to realize non–spherical principal series for $SL_2(\mathbb{R})$ as subrepresentations of $L^2(\Gamma(N)\backslash SL_2(\mathbb{R}))$ for $N \geq 3$, where $\Gamma(N)$ is the principal congruence subgroup of $SL_2(\mathbb{R})$ of level N.

Thanks to the ESI Senior Research Fellow Programme, I was able to invite the following visitors: D. Adamovic, M. Primc, M. Tadic and M. Hanzer. With M. Hanzer I worked on the description of the local theta correspondence for the dual pairs $\widetilde{Sp(2n)} \times O(2m+1)$ over p–adic fields in order to understand the reducibility of parabolic induction for metaplectic groups $\widetilde{Sp(2n)}$. The two papers concerning this work are in preparation. With M. Tadic I discussed automorphic duals (as defined by Burger–Sarnak–Li) in order to the apply methods in my works on the existence of cusp forms to an anlysis of the automorphic spectrum. With M. Primc and M. Adamovic I discussed possible other interpretation of the paper *On the cusp forms for the congruence subgroups of* $SL_2(\mathbb{R})$ in the theory of Vertex operator algebras where some types of such automorphic forms show up.

Preprints contributed: [2119], [2120], [2121]

Herbert Kurke, Denis Osipov, Alexander Zheglov

In preprint [Ku] we investigated new geometric objects $\overset{\circ}{X}_\infty = (C, \mathcal{A})$, which are ringed spaces: formal punctured ribbons with the underlying topological space C as algebraic curve. We introduced the notion of a torsion free sheaf on a ribbon. The importance of such sheaves followed from theorem 1 of preprint [Ku], where torsion free sheaves on some ribbons plus some geometrical data such as formal trivialization of sheaves, local parameters at smooth points of ribbons and so on are in one-to-one correspondence with generalized Fredholm subspaces of two-dimensional local fields.

These investigations are part of a program to establish a mulidimensional analogue of the well-known and fruitful interrelation between KdV- or, more general, KP-equations, and algebraic curves with additional geometric data on the other side. The geometric objects encode spectral properties of rings of germs of linear differential operators (since the point of view is purely local, no boundary or compactness, the spectrum is continuous and can be interpreted as an algebraic curve in the 1-variable case). The KP-hierarchy are the equations to describe isospectral deformations.

To our current state of knowledge, "formal ribbons" plus additional geometric data seem to be adequate geometric objects to encode spectral properties in the 2-dimensional case. Local fields $\mathbf{C}((z_1))((z_2)) = V$ come into the game, since V is a representation of the ring of pseudodifferential operators $\mathcal{O}((\partial_1^{-1}))((\partial_2^{-1}))$, where $\mathcal{O}$ is a ring of germs of analytic or formal functions $f(x_1, x_2)$ on $(\mathbf{C}^2, 0)$, $\partial_1 = \frac{\partial}{\partial x_1}$, $\partial_2 = \frac{\partial}{\partial x_2}$ (see theorem 1 of [Ku]).

There are many activities in this direction, for an (incomplete) survey on recent activities one can consult [Pr].

During our stay at ESI we investigated torsion free sheaves on ribbons $(C, \mathcal{A})$ and proved that if the underlying curve C of a ribbon is a smooth curve and for any small open $U \in C$ there are sections $a \in \Gamma(U, \mathcal{A}_1)$, $a^{-1} \in \Gamma(U, \mathcal{A}_{-1})$, then every torsion free sheaf on the ribbon $(C, \mathcal{A})$ is a locally free sheaf on a ringed space $(C, \mathcal{A})$. We remark that this condition is satisfied, for example, when the ribbon $(C, \mathcal{A})$ comes from a smooth curve C, which is a Cartier divisor on algebraic surface.

Therefore it is important to study locally free sheaves on ribbons $(C, \mathcal{A})$. We restrict ourself to the Picard group of a ribbon. In [Ku] we investigated the Picard group as a set, see proposition 5, example 8 in [Ku]. But it was not clear, what are the deformations (local or global) of elements of $Pic(\overset{\circ}{X}_\infty)$. We studied the groups $Pic(\overset{\circ}{X}_{\infty,S})$ and $Pic(X_{\infty,S})$ for an arbitrary affine scheme S as functors on the category of affine schemes from the point of view of representativity or formal representativity of these functors by a scheme or a formal scheme. We remark that the representativity of the functor $Pic(X_{\infty,S})$ by a scheme follows from Lipman's results, and the second functor is mapped in the first functor.

At first, we studied the tangent spaces to this functors. In article [Zh] the "picture cohomology" $H^0(W)$, $H^1(W)$, $H^2(W)$ were introduced for a generalized Fredholm subspace W of a two-dimensional local field. These cohomology groups coincide with the cohomology groups of a line bundle on an algebraic surface when a ribbon and a line bundle on it come from an algebraic surface and a line bundle on this surface. We investigated the picture cohomology groups of generalized Fredholm subspaces W and related them with some groups which depend on cohomology groups of sheaves $\mathcal{F}_W$ and $\mathcal{F}_{W,0}$ on the curve C ($W \longleftrightarrow \mathcal{F}_W$ is a generalized Krichever-Parshin correspondence.) Due to this result we obtained that the kernel of the natural map from tangent space of functor $Pic(X_{\infty,S})$ to tangent space of functor $Pic(\overset{\circ}{X}_{\infty,S})$ coincides with the first picture cohomology of the structure sheaf, and cokernel of this map coincides with the second picture cohomology of the structure sheaf.

Further we investigated the Picard functors on ringed spaces $X_{\infty,S}$ and $\overset{\circ}{X}_{\infty,S}$ as formal functors on Artinian rings. We proved that if the first picture cohomology group of the structure sheaf of a ribbon $\overset{\circ}{X}_\infty$ is finite-dimensional over the ground field k and $char\ k = 0$, then the formal Picard functor $\widehat{Pic}(\overset{\circ}{X}_\infty)$ is representable by a formal group, which can be decomposed in the product of two formal groups, where the first one is connected with the formal Picard functor $\widehat{Pic}(X_\infty)$ and the second one coincides with the formal Brauer group of algebraic surface when the ribbon $\overset{\circ}{X}_\infty$ comes from an algebraic surface and a curve on it.

We remark that the above map from $Pic(\overset{\circ}{X}_{\infty,S})$ (S in an Artinian ring) to the formal Brauer group of algebraic surface can be desribed in terms of gerbes in the spirit of Brylinski's book [Br].

We obtained also several results towards the global representativity of the functor $Pic(\overset{\circ}{X}_{\infty,S})$ on affine schemes S by a formal scheme.

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[Zh] Zheglov A.B., Osipov D.V., *On some questions related to the Krichever correspondence*, Matematicheskie Zametki, n. 4 (81), 2007, pp. 528-539 (in Russian); english translation in Mathematical Notes, 2007, Vol. 81, No. 4, pp. 467-476; see also e-print arXiv:math/0610364 .

Preprints contributed: [2094]

Werner Ballmann

Let me start by mentioning that my lecture notes in Kähler geometry were published in 2006, see [Ba]. They owe a lot to my last stay at the ESI in 2005, when I gave a course on Kählerian manifolds and had the opportunity to concentrate on writing the notes. Another publication that has profited much from my stays at the ESI in 2004 and 2005 is [BBC], a first article in a series of (at least) three articles in which we study boundary value problems for Dirac operators and applications to index theory.

During my present stay I worked on the second article in this series. We study applications of our results on elliptic boundary value problems to complete Riemannian manifolds with pinched negative curvature and finite volume. One of our aims is a different approach to the results of Barbasch and Moscovici, who treat the most interesting case of locally symmetric spaces of rank one, that is, of finite volume quotients of hyperbolic spaces and whose proof relies on a trace formula. In the case where the ends of a manifold look like the ends of such spaces, *locally symmetric cusps*, the methods of Barbasch and Moscovici do not apply. Our approach addresses the geometry of the manifolds along the ends only. In the case of locally symmetric cusps we need to calculate several quantities which appear as contributions of the ends to the Atiyah-Singer index formula. During my stay I found a way to determine the high energy part of the corresponding η-invariants, motivated by earlier work of Deninger and Singhof. We are optimistic that the article will be finished in the near future.

Parallel to my work with Brüning and Carron, but with a somewhat different viewpoint, I collaborate with Christian Bär on boundary value problems for elliptic differential operators of order one. This work started in 2002, we collaborated on this project during my stay at the ESI in 2004, during this year's stay I was able to advance the project considerably, and I am confident that we will publish our results soon. We develop a very simple approach to elliptic boundary value problems, their regularity theory, and related index formulas of Atiyah-Patodi-Singer type.

References

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[BBC] W. Ballmann, J. Brüning, & G. Carron: Regularity and index theory for Dirac-Schrödinger systems with Lipschitz coefficients. *J. Math. Pures Appl.* 89 (2008), 429-476.

Roberto Longo

During my stay at the Schrödinger Institute in Vienna, beside my activity as one of the organizers of the research program on "Operator Algebras and Conformal Field Theory" decribed in the programme report, I have pursued my research activity mainly in two directions: Noncommutative Geometry and Local Conformal Nets:

Connes Noncommutative Geometry is, in a sense, the study of finite-dimensional noncommutative manifolds. My objective here is to interpret certain conformal models as infinite-dimensional noncommutative manifolds. The natural candidates are supersymmetric models. I wanted to study the representation theory of these models and construct a Connes spectral triple associated with certain representations. By regarding a certain type of superselection sector as the analog of an elliptic differential operator on an infinite-dimensional noncommutative manifold, I wish to associate a Jaffe-Lesniewski-Osterwalder entire cyclic cocycle to it and want to understand how this cohomology class depends on the sector. As explained in my previous work, one aims in this way to formulate a QFT index theorem, namely an analog of the celebrated Atiyah-Singer index theorem on an infinite-dimensional non-commutative manifolds. Note that the existing index theorems (cf. Connes book) concern the vacuum representation while the present project concerns the tensor category of sectors. During my permanence at the ESI I could get further in this research project in collaboration with S. Carpi, R. Hillier, Y. Kawahigashi. We have now obtained spectral triples associated with Ramond representations of the Super-Virasoro algebra. We have put our result in a paper "Spectral Triples and the Super-Virasoro Algebra" that is also available a ESI preprint. Boundary CFT:

H. Rehren and myself have recently described the general structure of a local conformal net of von Neumann algebras on a half-plane. Some aspects of conformal field theory, when analyzed in this setting, show that the emerging structure can be new. In this context one point that one wants to explore in this research project is the thermalization effect. Indeed we expect a Unruh-Hawking effect to have a different form in the presence of a boundary. We want to understand the modular flow of an observer having a double cone as his own spacetime and whether he feels any thermalization from the boundary. During my stay at the ESI I could collaborate with H. Rehren and P. Martinetti and we have now have geometric description of the modular group associated with a specific class of states of the von Neumann algebra of a double cone in Boundary CFT. The results will appear in a paper in preparation.

Seminars and colloquia outside of conferences

2008 01 16, A. Sandvik: “Variational Monte Carlo simulations with MPS and related tensor-network states”
2008 01 16, G. Vidal: “Entanglement Renormalization, Quantum Criticality and Topological Order”
2008 01 16, S. Walter: “Hermann Minkowski and the Scandal of Spacetime”
2008 01 17, E. Rico: “2D Multipartite Valence bond States in Quantum Antiferromagnets”
2008 01 17, R. Orus: “Entanglement and the simulation of 2-D systems”
2008 01 17, V. Murg: “Simulating frustrated quantum systems using PEPS”
2008 01 18, G. Crosswhite: “Building machines to represent quantum systems: the equivalence between finite state automata and matrix product states”
2008 01 18, L. Tagliacozzo: “Scaling of entanglement support in matrix product states”
2008 01 18, N. Schuch: “the computational complexity of finding MPS ground states”
2008 01 23, A. Kiejna: “Cohesion and impurity segregation at grain boundary of iron”
2008 01 23, D. Reith: “Ab initio modelling of Fe-rich Fe-Cu alloys”
2008 01 23, E. Wachowicz: “The effect of various impurity concentrations on the Sum 5 Fe(210) grain boundary”
2008 01 23, J. Hafner : “Adsorption of atoms and small molecules on quasicrystalline surfaces”
2008 01 23, M. Krajci: “Quasicrystals: Structure and properties of bulk, surface and thin films”
2008 01 23, M. Sob: “Electronic structure of indium-tin alloys”
2008 01 23, M. Stöhr:“Cluster expansion studies of bulk alloys and alloy surfaces”
2008 01 23, T. Ossowski: “Cohesion at chromium grain boundary”
2008 01 23, V. Vitek: “Application of ab initio methods in studies of properties of metallic materials”
2008 01 24, M. Jahnatek: “Ab-initio modelling of the response of intermetallics to ternsile and shear loading”
2008 01 24, M. Zeleny: “Ab-initio study of structural and magnetic properties of iron nanowires”
2008 01 24, P. Blonski:“Structure and magnetism of small transition metal clusters”
2008 01 24, P. Lazar: “Improving ductility by microalloying: an ab-inito study of NiAl”
2008 01 24, P. Mohn: “Magnetism without d- and f-electrons”
2008 01 28, R. Blumenhagen: “D-brane Instanton Effects in String Compactifications”
2008 02 05, J. Jonsson: “Combinatorial properties of hard particles on grids”
2008 02 12, J. Marckert: “A family of growing triangulations”
2008 02 12, P. Bolhuis: “Opening lecture and Path sampling of transitions in proteins”
2008 02 13, C. Dellago: “Studying phase transformations with transition path sampling”
2008 02 13, T. Schilling: “Depletion induced percolation- and phase-transitions”
2008 02 14, J. Rogal: “Multi-state transition path sampling for systems with metastable intermediates”
2008 02 14, T. Woolf: “Weighted Ensemble Methods, Stochastic Simulation, and Sampling of Multiple Pathways”
2008 02 15, A. Dinner: “Automated analysis of path sampling simulations reveals a two-step nucleotide-flipping mechanism for a DNA repair protein”

2008 02 18, A. Laio: "Folding of small proteins in explicit solvent by the combined use of metadynamics and replica exchange"
2008 02 18, A. Oganov: "Evolutionary crystal structure prediction: Finding the global energy minima for periodic solids"
2008 02 18, B. Ensing: "Poor man's metadynamics"
2008 02 18, K. Reuter: "Error-controlled multiscale modeling approaches to surface chemistry and catalysis"
2008 02 18, L. Maragliano: "Single-sweep methods for free energy calculations"
2008 02 18, N. Mousseau: "The dynamical activation-relaxation technique (DART): an on-the-fly kinetic Monte-Carlo algorithm"
2008 02 19, D. Chandler: "Transition path sampling of large fluctuation functions and non-equilibrium order-disorder transitions"
2008 02 19, J. Kurchan: "Finding rare trajectories"
2008 02 19, K. Fichthorn: "Accelerated Molecular Dynamics with the Bond-Boost Method"
2008 02 19, M. Grünwald: "Precision shooting: sampling diffusive transition pathways"
2008 02 19, S. Corteel: "Permutation tableaux and the partially asymmetric exclusion process "
2008 02 19, S. Friedland: "Counting matchings in graphs, with applications to the monomer-dimer mode"l
2008 02 19, T. Miller: "Sampling diffusive transition paths"
2008 02 19, T. van Erp: "Efficient path sampling on multiple reaction channels"
2008 02 20, A. Dinner: "Umbrella sampling for non-equilibrium processes"
2008 02 20, B. Peters: "Likelihood Maximization for Obtaining Reaction Coordinates"
2008 02 20, M. Athenes: "Mapping the equilibrium and non-equilibrium entropy landscapes of metastable systems: the path-sampling approach"
2008 02 20, P. Maragakis: "A Differential Fluctuation Theorem"
2008 02 20, R. Chelli: "Calculation of the potential of mean force from non-equlibrium measurements via maximum likelihood estimators"
2008 02 20, R. Vuilleumier: "Microscopic velocity field around a diffusing particle"
2008 02 20, S. Wiggins: "Recent advances in the high dimensional Hamiltonian dynamics and geometry of reaction dynamics"
2008 02 21, C. Schütte: "New Approaches to Multiscale Modelling of Metastable Systems"
2008 02 21, C. Valeriani: "Evidence for out-of-equilibrium crystal nucleation in suspensions of oppositely charged colloids"
2008 02 21, D. Zahn: "Nucleation Events and Self-Organization"
2008 02 21, F. Gervasio: "The folding mechanism of beta-hairpin from PT- metaD and pathbased collective variables simulations"
2008 02 21, J. Chodera: "Master equation models of protein folding and dynamics from all-atom molecular dynamics simulations in explicit solvent "
2008 02 21, M. Venturoli: "Kinetics of phase transitions in two dimensional Ising models studied with the string method"
2008 02 21, R. Allen: "Homogeneous nucleation under shear in a two-dimensional Ising model"
2008 02 21, R. Elber: "The recovery stroke of myosin: Atomically detailed simulations by Milestoning"
2008 02 21, T. Woolf: "Dynamic Importance Sampling for Biomolecule Transitions: Progress and the Future"
2008 02 22, G. Hummer: "Free energies and kinetics of molecular systems from coarse master equations"
2008 03 04, B. Vető : "Models of the true self-avoiding walk on Z"
2008 03 11, M. Katori: "Maximum height distribution of noncolliding Bessel bridges "
2008 03 19, P. Freund: "A Passion for Discovery"
2008 04 08, V. Pasquier: "Alternating sign matrices from a physicist point of view"
2008 04 11, A. Papadopoulos: "Actions of the mapping class groups"
2008 04 15, P. Forrester: "Non-intersecting paths and random matrices"
2008 04 15, Y. Yakubovich: "Limit shapes for random integer partitions"

2008 04 22, P. Chassaing: “Statistics of random words and of random Lyndon words”
2008 04 24, S. Souaifi: “Harmonic Analysis on reductive symmetric spaces”
2008 04 24, V. Anagnostopoulou: “Which beta-shifts have a largest invariant measure?”
2008 04 29, O. Foda: “Free fermions and plane partitions”
2008 05 06, S. Janson: “Graph limits and exchangeable random graphs”
2008 05 15, W. Ballmann: “Spaces of Nonpositive Curvature: Rank One and Rank Rigidity”
2008 05 19, A. Guttmann: “Quasi-prudent and prudent self-avoiding walks and polygons”
2008 05 19, B. Vetö: “Models of the true self-avoiding walk on Z”
2008 05 19, C. Richard: “A radius of gyration study for square lattice ploygons”
2008 05 19, J. Jacobsen: “Boundary loop models”
2008 05 20, J. de Gier: “Punctured plane partitions, restricted fully packed loop diagrams and nest distribution functions”
2008 05 20, K. Shigechi: “Orthogonal basis and the quantum Knizhnik-Zamolodchikov equation of level one”
2008 05 20, P. Pyatov: “Stochastic raise and peel model and combinatorics of Pascal’s hexagon”
2008 05 20, R. Behrend: “Higher spin altrnating sign matrices”
2008 05 20, X. Viennot: “An alternative approach to alternating sign matrices”
2008 05 21, B. Salvy: “Gfun: 15 years later”
2008 05 21, G. Duchamp: “Algebras of diagrams and the EGF Hadamard Product”
2008 05 21, J. Crepeau: “Josef Stefan and Josef Loschmidt: Colleagues in Vienna, Contrasts of Stigler’s Law”
2008 05 22, F. Colomo: “The limit shape of large Alternating Sign Matrices”
2008 05 22, G. Slade: “Invasion percolation on a regular tree”
2008 05 22, O. Foda: “Free fermions, plane partitions and integrable hierarchies”
2008 05 22, P. Bleher: “Exact solution of the six-vertex model with domain wall boundary conditions”
2008 05 22, S. Okada: “A compound determinant identity and its application”
2008 05 23, B. Rath: “Erdős-Rényi random graphs + forest fires = self organized criticality”
2008 05 23, M. Noy: “Random planar graphs”
2008 05 26, A. Berkovich: “GBG rank of partitions and counting at a root of unity”
2008 05 26, E. Guitter: “The three-point function of planar quadrangulations”
2008 05 26, J. Bouttier: “Statistics of geodesics in large quadrangulations”
2008 05 26, R. van der Hofstad: “Random graph asymptotics on high-dimensional tori”
2008 05 27, A. Razumov: “Enumerations of alternating-sign matrices without Izergin-Korepin determinant”
2008 05 27, F. Gesztesy: “Some Remarks on Generalized Polar Decompositions of Closed Hilbert Space Operators”
2008 05 27, M. Ishikawa: “Littlewood’s (Cauchy’s) formulae of Schur functions and constant term expressions for the refined enumeration problems of TSSCPPs”
2008 05 27, P. Di Francesco: “Integrable Combinatorics: from qKZ to TSSCPP”
2008 05 27, V. Korepin: “History of domain wall boundary conditions for six vertex model”
2008 05 27, Y. Stroganov: “Three colour statistical model with domain wall boundary conditions”
2008 05 28, D. Dhar: “Exact entropy of dimer coverings of lattices in three and more dimensions”
2008 05 28, Y. Le Borgne: “A normalization formula for Jack polynomials in superspace”
2008 05 29, A. Owczarek: “A tale of two napkins: Interacting partially directed walks with a tensile force and variable flexibility”
2008 05 29, A. Rechnitzer: “Atmospheres, kinetic growth and approximate counting”
2008 05 29, B. van Rensburg: “Directed paths in a layered environment”
2008 05 29, M. Katori: “Noncolliding Brownian motions with arbitrary initial configuration and multiple Hermite polynomials”
2008 05 30, A. Vershik: “Combinatorics and integration over random configurations”
2008 05 30, H. Posch: “Nonequilibrium Stationary States”

2008 05 30, K. Khanin: “Exits from a semi-infinite tube”
2008 05 30, T. Prellberg: “Counting Defective Parking Funktions”
2008 06 02, A. Vulpiani: “Some aspects of the fluctuation-dissipation relation”
2008 06 02, D. Ruelle: “Nonequilibrium statistical mechanics and smooth dynamical systems I”
2008 06 02, F. Bonetto: “Perturbative methods for dynamical systems theory and statistical mechanics”
2008 06 02, L. Rey-Bellet: “Large deviations for billiards and nonuniformly hyperbolic dynamical systems”
2008 06 02, L. Young: “Reliability of neural oscillator networks”
2008 06 03, D. Mukamel: “Ordering and criticality in one dimensional driven systems”
2008 06 03, D. Ruelle: “Nonequilibrium statistical mechanics and smooth dynamicals systems II”
2008 06 03, D. Sanders: “Rare events and long-range correlations in systems with many random walkers”
2008 06 03, E. Presutti: “Persistence of randomness in macroscopic limits I”
2008 06 03, G. Andrews: “Partitions, Durfee Symbols and the Atkin-Garvan Moments of Ranks ”
2008 06 03, L. Rondoni: “Onset of diffusive behavior in confined transport systems”
2008 06 03, Y. Zhang: “Drinfeld twists, symmetric Bethe vectors and correlation functions in SUSY integrable models ”
2008 06 04, E. Presutti: “Persistence of randomness in macroscopic limits II”
2008 06 04, G. Jona-Lasinio: “Nonequilibrium thermodynamics: a self-contained macroscopic description of diffusive systems”
2008 06 04, O. Lanford: “Discretization of expanding maps and percolation on a tree”
2008 06 05, A. Kupiainen: “Diffusion of energy in a coupled map lattice”
2008 06 05, B. Schlein: “Dynamics of Bose-Einstein condensates”
2008 06 05, C. Pillet: “C^*-dynamical systems and nonequilibrium quantum statistical mechanics”
2008 06 05, C. Pillet: “C^*-dynamical systems and nonequilibrium qunatum statistical mechenics I”
2008 06 05, G. Benettin: “The two-dimensional vs the one-dimensional Fermi-Pasta Ulam problem”
2008 06 06, A. Politi: “Heat conductivity as a testing ground for the characterization of out-of-equilibrium steady states ”
2008 06 06, J. Eckmann: “A model of heat transport”
2008 06 06, P. Gaspard: “Heat conduction and Fourier’s law in a class of many-particle dispersing billiards”
2008 06 06, P. Jacquet: “Transport properties of a chain of dynamical quantum dots”
2008 06 09, D. Dolgopyat: “Martingale approach to Limit Theorems for Hyperbolic Dynamical systems”
2008 06 09, N. Chernov: “Coupling methods for hyperbolic maps and flows”
2008 06 09, P. Balint: “An Application of Young’s tower method: exponential decay of correlations for multidimensional dispersing billiards”
2008 06 10, B. Pittel: “On a random graph evolving by degrees”
2008 06 10, H. Hu: “Convergence rates of the transfer operators for sigma finite measures”
2008 06 10, N. Haydn: “the distribution of measures of cylinder stets for uniformly strong mixing measures”
2008 06 10, Y. Pesin: “Thermodynamics of towers and the liftability problem”
2008 06 11, O. Bernardi: “On the growth rate of minor-closed classes of graphs”
2008 06 12, F. Barra: “Dynamics in the Self-Similar Lorentz Channel”
2008 06 12, S. Luzzato: “Invariant measures for interval maps with critical points and singularities”
2008 06 12, Y. Kifer: “Noncenvergence examples in averaging”
2008 06 16, A. Wilkinson: “From uniform to partial hyperbolicity”
2008 06 16, E. Scheidegger: “Towards Open String Mirror Symmetry for One-Parameter Calabi-Yau Hypersurfaces Part II”
2008 06 16, J. Knapp: “Towards Open String Mirror Symmetry for One-Parameter Calabi-Yau Hypersurfaces Part I”
2008 06 16, V. Baladi: “Some ”new“ Banach spaces, and why they are useful for dynamics”
2008 06 17, M. Lenci: “infinite-volume mixing”

2008 06 17, N. Simanyi: “Homotopical Rotation Numbers of 2D Billiards”
2008 06 17, T. Gilbert: “Equilibrium and non-equilibrium Galton boards”
2008 06 18, C. Liverani: “Statistical properties of infinite dimensional systems”
2008 06 19, J. de Simoi: “Stability and Instability results in a model of Fermi Acceleration”
2008 06 19, P. Wright: “Some rigorous results for the periodic oscillation of an adiabatic piston”
2008 06 19, V. Kaloshin: “Hausdorff dimension of oscillatory motions for the 3 body problem”
2008 06 23, A. Gorodetski: “the size of stochastic layer of the standard map”
2008 06 23, J. Marklof: “The Boltzmann-Grad limit of the periodic Lorentz gas”
2008 06 23, L. Bunimovich: “Where to place a hole to achieve a maximal excape rate”
2008 06 23, R. Markarian: “Non-conservative billiards. Dominated splitting”
2008 06 23, W. Ott: “Dissipative homoclinic loops and rank one chaos”
2008 06 24, A. Török: “Extreme value distributions for non-uniformly hyperbolic dynamical systems”
2008 06 24, F. Ledrappier: “Fluctuations of the ergodic sums for the horocycle flow on ablian covers of hyperbolic surfaces”
2008 06 24, F. Pene: “Some properties of the planar Lorentz gas”
2008 06 24, M. Demers: “Billiards with Holes ”
2008 06 24, M. Tsujii: “Quasi-compactness of transfer operators for contact Anosov flows”
2008 06 25, J. Alves: “Liftable absolutely continuous invariant measures”
2008 06 25, M. Pollicott: “Large deviations for intermittent maps”
2008 06 25, S. Gouëzel: “Necessary and sufficient conditions for limit theorems in Gibbs-Markov maps”
2008 06 25, T. Yarmola: “An example of a pathological random perturbation of the Cat Map”
2008 06 26, D. Li: “Complex blowups of some fluid dynamics equations and Renormalization Group Method”
2008 06 26, G. Gentile: “Periodic solutions for a class of nonlinear partial differential equations in higher dimension”
2008 06 26, G. Keller: “Globally coupled piecewise expanding maps with bistable behaviour”
2008 06 26, H. van Beijeren: “Green-Kubo formalism for solids”
2008 06 26, R. Klages: “Deterministic random walks in maps and billiards”
2008 06 27, I. Melbourne: “Large and moderate deviations for slowly mixing nonuniformly hyperbolic systems”
2008 06 27, M. Wojtkowski: “Abstract fluctuation theorem”
2008 07 02, A. Gorodetski: “Hyperbolicity of the trace map and spectral properties of the discrete Schrodinger operator with Fibonacci potential.”
2008 07 02, P. Collet: “Exponential and variance inequalities in dynamical systems ”
2008 07 03, N. Grbac: “Some consequences of Arthur’s Conjecture”
2008 07 21, L. Erdős: “Quantum Brownian motion as a scaling limit of random Schrödinger evolution I”
2008 07 21, V. Jaksic: “Entropic fluctuations in statistical mechanics I”
2008 07 22, I. Rodnianski: “Evolution problem in General Relativity I”
2008 07 22, L. Erdős: “Quantum Brownian motion as a scaling limit of random Schrödinger evolution II”
2008 07 23, I. Rodnianski: “Evolution problem in General Relativity II”
2008 07 23, V. Jaksic: “Entropic fluctuations in statistical mechanics II”
2008 07 24, H. Spohn: “Kinetic theory of weakly interacting quantum fluids I ”
2008 07 24, M. Salmhofer: “Renormalization group methods for quantum many-body systems I”
2008 07 25, M. Salmhofer: “Renormalization group methods for quantum many-body systems II”
2008 07 26, H. Spohn: “Kinetic theory of weakly interacting quantum fluids II”
2008 07 28, B. Nachtergaele: “Quantum Spin Dynamics and Applications to Quantum Information and Computation I”
2008 07 28, M. Loss: “A dynamic approach to some problems in the calculus of variations I”
2008 07 29, B. Nachtergaele: “Quantum Spin Dynamics and Applications to Quantum Informationand Computation II ”
2008 07 29, J. Schenker: “On random Schrödinger operators I”

2008 07 30, M. Loss: “A dynamic approach to some problems in the calculus of variations II”
2008 07 31, J. Schenker: “On random Schrödinger operators II”
2008 09 03, M. Choda: “Entropy on the matrix algebras”
2008 09 03, R. Conti: “Trees and permutation automorphisms of the Cuntz algebras”
2008 09 05, C. Jäkel: “Stability and Related Properties of Vacua and Ground States”
2008 09 08, D. Buchholz: “The resolvent algebra: A new approach to canonical quantum systems”
2008 09 08, G. Lechner: “Deformations of Wightman Quantum Field Theories”
2008 09 08, G. Morsella: “Scaling limits for subsystems and Doplicher-Roberts reconstruction”
2008 09 08, H. Bostelmann: “The structure of dilation symmetries in the scaling limit of a quantum field theory”
2008 09 09, D. Voiculescu: “Free Analysis: the analogue of the Riemann sphere”
2008 09 09, F. Radulescu: “Type II1 von Neumann algebra representations for arithmetical Hecke operators”
2008 09 09, J. Roberts: “Ergodicity, quantum symmetry and tensor categories”
2008 09 11, D. Bisch: “The planar algebra of group-type subfactors”
2008 09 11, H. Wenzl: “Centralizers for spinor representations”
2008 09 11, M. Asaeda: “Non-existence of certain finite depth subfactors”
2008 09 11, M. Izumi: “Classification of certain tensor categories”
2008 09 12, D. Guido: “Scaling limits and quantum Gromov-Hausdorff convergence”
2008 09 12, K. Fredenhagen: “The time slice axiom in perturbative Quantum Field Theory”
2008 09 12, S. Doplicher: “Quantum Spacetime and Noncommutative Geometry”
2008 09 15, D. Adamovic: “On the representation theory of a family of C2-cofinite vertex operator superalgebras”
2008 09 15, M. Weiner: “Local energy bounds”
2008 09 15, N. Nikolov: “OPE algebras in globally conformal invariant QFT and beyond”
2008 09 15, S. Carpi: “From vertex operator algebras to conformal nets”
2008 09 16, D. Evans: “Modular invariants and twisted K-theory”
2008 09 16, I. Runkel: “Boundary CFT and Frobenius Algebras”
2008 09 16, K. Barron: “N=2 genus-zero worldsheets and N=2 superconformal field”
2008 09 18, A. Henriques: “From elliptic cohomology to conformal nets”
2008 09 18, A. Wassermann: “Connes fusion for twisted loop groups”
2008 09 18, G. Elliott: “The cone of lower semicontinuous traces on a C*-algebra”
2008 09 18, V. Petkova: “Pentagon equations and their solutions in non-critical string theory”
2008 09 19, A. Kirillov Jr.: “G-crossed categoris and G-modular functor”
2008 09 19, B. Schroer: “Causal localization, inside/outside entanglement, entropy and all that”
2008 09 19, C. Schweigert: “Modules and bimodules for bundle gerbes: Wess-Zumino terms for defects and boundaries”
2008 09 19, M. Müger: “Modular extensions, crossed G-categories and permutation-orbifolds”
2008 09 22, R. Suszek: “World-sheet structures for defect junctions in 2d sigma-models”
2008 10 06, A. Lukas: “Lecture on Heterotic String Model Building I”
2008 10 06, K. Becker: “Flux backgrounds for heterotic strings”
2008 10 06, L. Anderson: “An algorithmic approach to heterotic compactification”
2008 10 06, V. Braun: “Lecture on Heterotic String Model Building II”
2008 10 07, A. Lerda & M. Billo: “Lecture on String Instanton Calculus”
2008 10 07, A. Uranga: “Lecture on D-brane model building, instantons etc.”
2008 10 07, M. Schmidt-Sommerfeld: “Multi D-instantons Effects in String Compactifications”
2008 10 07, T. Grimm: “Mediation of Flux Supersymmetry Breakin”
2008 10 08, F. Witt: “SO(d,d)–invariant functionals in supergravity”
2008 10 08, H. Jockers: “Effective superpotentials for compact D5-brane Calabi-Yau geometries”
2008 10 08, M. Becker: “New Heterotic Flux Compactification”
2008 10 08, M. Bianchi: “Lecture on Gepner Models”

2008 10 08, M. Herbst: “Lecture on D-branes in LG models and matrix factorisation”
2008 10 09, A. Braun: “D7-brane moduli and their stabilization via F-Theory”
2008 10 09, C. Beasley: “Lecture on GUTs and Exceptional Branes in F-Theory”
2008 10 09, M. Wijnholt: “Lecture on F-Theory model building”
2008 10 09, S. Schafer-Nameki: “SUSY breaking in F-theory GUTs”
2008 10 10, A. Kashani-Poor: “N=1 solutions from N+2 theories”
2008 10 10, D. Cassani: “Dimensional reductions on SU(3) x SU(3) structures and N=1 vacuum conditions”
2008 10 10, L. Martucci & P. Koerber: “Lecture on Generalized Geometry and Flux Compactifications”
2008 10 10, M. Douglas: “Discussion on mathematical challenges in String Phenomenology”
2008 10 13, A. Collinucci: “D-brane Deconstructions in IIB Orientifolds”
2008 10 13, A. Lukas: “String vacua and Algebraic Geometry: an algorithmic approach”
2008 10 13, J. Gray: “Aspects of algorithmic algebraic geometry in string phenomenology”
2008 10 13, M. Kreuzer: “The Toric toolbox: Calabi-Yau constructions and data mining”
2008 10 13, V. Braun: “Calabi-Yau Metrics and the Spectrum of the Laplacian”
2008 10 14, A. Tomasiello: “Supersymmetric flux vacua in string theory (and their CFT duals)”
2008 10 14, D. Orlov: “On Derived category of Singularities”
2008 10 14, E. Scheidegger: “Towards Open String Mirror Symmetry for compact Calabi-Yau”
2008 10 14, F. Everitt: “The History of Gravity Probe B”
2008 10 14, M. Herbst: “On matrix factorizations of complete intersections”
2008 10 15, D. Orlov: “Spectrum of a category”
2008 10 15, M. Kreuzer: “Conifold transitions and Mirror Symmetry”
2008 10 16, A. Iliev: “Fano threefolds, cubics and algebraic integrable systems”
2008 10 16, V. Golyshev: “On quantum motives”
2008 10 16, V. Prizhalkovskii: “On Landau Ginzburg Models of Fanos”
2008 10 17, A. Corti: “On the quartic threefold”
2008 10 17, A. Iliev: “Cubics, integrable systems, and varieties of type Fano-Calabi-Yau”
2008 10 17, H. Iritani: “Integral and integral structures in toric quantum cohomology I”
2008 10 17, V. Golyshev: “How to discover Fano varieties”
2008 10 18, C. Doran: “Algebraic Cycles and Homological Mirror Symmetry”
2008 10 18, H. Iritani: “Integral and integral structures in toric quantrum cohomoology II”
2008 10 18, L. Katzarkov: “Conic bundles old and new”
2008 10 27, A. Carey: “Spectral flow in von Neumann algebras”
2008 10 29, J. Bouveresse: “Ludwig Boltzmann und das Problem der Erklärung in der Wissenschaft”
2008 10 31, D. Burde: “Crystallographic Groups and Lie Algebra Representations”
2008 10 31, K. Auginger: “Gleichungstheorien algebraischer Strukturen”
2008 10 31, K. Schmidt: “Kommutative Algebra und Ergodentheorie”
2008 10 31, M. Goldstern: “Der Cloneverband auf endlichen und abzählbaren Mengen”
2008 10 31, M. Kreuzer: “Toric Geometry and Applications”
2008 10 31, W. Herfort: “Gleichungstheorien algebraischer Strukturen”
2008 11 03, G. Landi: “Monopoles and Instantons on noncommutative spaces”
2008 11 03, J. Conze: “The CLT for sequences of matrices in $SL(d, Z^+)$ and a quenched CLT”
2008 11 03, M. Gordin: “Baker sequences and multiparameter martingale approximation”
2008 11 03, R. Verch: “Local thermal equilibrium and quantum energy inequalities for quantum fields on manifolds”
2008 11 04, F. Alcalde: “The branching number of a graphed pseudogroup”
2008 11 04, M. Keller: “The essential spectrum of the Laplacian on rapidly branching tessellations”
2008 11 04, R. Sharp: “Distortion and entropy for automorphisms of free groups”
2008 11 04, V. Jones: “Flatland, a great place to do algebra”
2008 11 04, Y. Guivarch: “Convergence to stable laws for affine stochastic recursions and spectral properties of some transfer operators”

2008 11 05, A. Erschler: “Poisson boundaries for random walks on amenable groups”
2008 11 05, B. Deroin: “Qualitative aspects of differential equations in the complex domain”
2008 11 05, H. Kosaki: “Trace Jensen Inequality in von Neumann algebras and related topics”
2008 11 05, W. Woess: “On the spectrum of lamplighter groups and percolation clusters”
2008 11 06, M. Wojtkovski: “Geometry of Kalman filters”
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DBE = Metastability and Rare Events in Complex Systems
GHZ = Profinite Groups
GS = Sypersymmetry and Noncommutative Quantum Field Theory
HAF = Ab-initio density-funtional Studies of Intermetallic Compounds
HB = Frontiers in Mathematical Biology
HSY = Summer School on "Current Topics in Mathematical Physics"
JF = Junior Fellow
KLR = Operator Algebras and Conformal Field Theory
KNB = Combinatorics and Statistical Physics
KS = Structural Probability
SCH = Guest of Prof. Schmidt
SCHW = Guest of Prof. Schwermer
SF = Senior Research Fellow
SFS = Senior Research Fellow Share
VWV = Tensor Network Methods and Entanglement in Quantum Many-Body Systems
YNG = Guest of Prof. Yngvason
YPS = Hyperbolic Dynamical Systems
15y = ESI - 15th Anniversary Celebration

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Adamovic Drazen, University of Zagreb, Department of Mathematics; 07.09.2008 - 23.09.2008, KLR;

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Andrews George E., Penn State University, Mathematics Department; 31.05.2008 - 06.06.2008, KNB;

Annunziata Mario Alberto, Scuola Normale Superiore, Pisa; 06.07.2008 - 19.07.2008, KNB;

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Pickl Peter, ETH Zürich, Theoretische Physik ; 03.03.2008 - 06.03.2008, YNG;

Pillet Claude-Alain, Université du Sud, Toulon-Var; 01.06.2008 - 06.06.2008, YPS;

Pinamonti Nicola, Universität Hamburg, II Institut f. theoretische Physik; 02.11.2008 - 14.11.2008, KLR;

Pinto Aline G.S., University of Brasilia, Department of Mathematics; 06.12.2008 - 22.12.2008, GHZ;

Pinto Paulo Jorge, Inst. Superior Técnico, Lisbon; 09.09.2008 - 17.09.2008, KLR;

Piotrowiak Sven, Universität Erlangen, Mathematisches Institut; 01.10.2008 - 03.10.2008, BW;

Pippan Peter, TU Graz; 16.01.2008 - 18.01.2008, VWV;

Pittel Boris, Ohio State University, Department of Mathematics; 31.05.2008 - 16.06.2008, KNB;

Pittet Christophe, University of Provence, CMI, Marseille; 02.11.2008 - 05.11.2008, KS; 07.11.2008 - 15.11.2008, KS;

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Ponsaing Anita, University of Melbourne; 14.05.2008 - 03.06.2008, KNB;

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Tomasiello Alessandro, Harvard University, Cambridge; 11.10.2008 - 15.10.2008, BDK;

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Zhang Yao-Zhong, University of Queensland; 31.05.2008 - 09.06.2008, KNB;

Zheglov Alexander, Moscow State University; 07.01.2008 - 02.02.2008, SF;

Zinn-Justin Paul, LPTHE, Univ. Pierre et Marie-Curie, Paris; 29.04.2008 - 02.05.2008, KNB;

Zint Natali, Universität Bielefeld, Faculty of Technology; 01.10.2008 - 04.10.2008, BW;

Zito Pasquale Anthony, Universitá di Roma "Tor Vergata"; 12.09.2008 - 20.09.2008, KLR;

Zoupanos George, National Technical University, Athens, Zografou; 04.12.2008 - 09.12.2008, GS;

Zsido Laszlo, University of Rome "Tor Vergata"; 24.10.2008 - 03.11.2008, KLR;

Zuk Andrzej, Université Paris 7; 07.12.2008 - 22.12.2008, GHZ;

Zyubin Sergey, Tomsk Polytechnic University; 23.08.2008 - 28.08.2008, BKR;