ESI **The Erwin Schrödinger International Institute for Mathematical Physics**

Boltzmanngasse 9/2
A-1090 Vienna, Austria

Scientific Report for 2011

Impressum: Eigentümer, Verleger, Herausgeber: The Erwin Schrödinger International Institute for Mathematical Physics, Boltzmanngasse 9, A-1090 Vienna.
Redaktion: Joachim Schwermer, Jakob Yngvason
Supported by the Austrian Federal Ministry of Science and Research (BMWF).

Contents

Preface

It came as a shock to the ESI leadership when they were informed at a meeting at the Austrian Ministry of Science and Research on October 27, 2010, that due to budgetary measures affecting more than 70 independent research institutions in Austria, funding of ESI would be terminated as of January 1st, 2011. In the wake of a very remarkable protest action by the international scientific community an agreement was reached between the Ministry and the University of Vienna to the effect that a new Research Centre ('Forschungsplattform') of the University with the same objectives and tasks as the ESI would become operational by June 1st, 2011. Based on a contractual agreement between the Faculty of Mathematics, the Faculty of Physics and the Rector of the University of Vienna, signed on January 20, 2011, this took place. The new research centre bears the same name and has the same physical location as the 'old' ESI. The Ministry has guaranteed to fund the 'new' ESI through the University with a somewhat reduced budget until 2014 with a possible extension to 2015. The Rectorate of the University was — and continues to be — most helpful and cooperative in implementing this agreement. Unfortunately the very successful Junior Research Fellows programme of the ESI had to be terminated due to lack of funds.

The organizational structure of the 'new' ESI is as follows: The Research Centre ESI is governed by a board ('Kollegium') of 6 members appointed by the Rector of the University after consultations with the Dean of the Faculty of Physics resp. the Faculty of Mathematics. It consists of the professors

Goulnara Arzhantseva (Faculty of Mathematics)

Adrian Constantin (Faculty of Mathematics)

Joachim Schwermer (Faculty of Mathematics)

Piotr T. Chruściel (Faculty of Physics)

Frank Verstraete (Faculty of Physics)

Jakob Yngvason (Faculty of Physics)

Following a recommendation by the Kollegium the Rector of the University of Vienna has appointed Joachim Schwermer as director of the ESI who is accountable to the Rector, and Goulnara Arzhantseva and Jakob Yngvason as deputies.

Although the financial and organizational uncertainties of the first half of the year 2011 made both short-term and longer term planning extremely difficult the ESI was able to maintain its scientific activities during this difficult period of transition. January 2011 saw two workshops, one on *Harmonic and Complex Analysis and its Applications* (organized by H.G. Feichtinger), and one on Erwin Schrödinger's scientific legacy. The latter workshop had been planned to commemorate Erwin Schrödinger's death in January 1961 — a commemoration made all the more poignant by coinciding almost exactly with the intended closure of the Institute by the Ministry of Science in January 2011.

With negotiations about the continued existence of the ESI under way the Institute was able to move ahead cautiously with its activities during the following months of 2011. In January

there were follow-up workshops to the earlier programmes on *Selected topics in spectral theory* (B. Helffer, T. Hoffmann-Ostenhof, A. Laptev, 2009) and on *Quantitative Studies of Nonlinear Wave Phenomena* (P.C. Aichelburg, P. Bizoń, W. Schlag, 2010), a *Seminar on Mathematical Relativity* (R. Beig, P. Bizoń, P. Chrusciel, H. Friedrich), and a further workshop on *Non-commutative geometry, scattering theory and the Witten index* (A.L. Carey, H. Grosse, F. Gesztesy, F. Sukochev).

The organization of the thematic programmes planned for 2011 was affected severely by the period of transition, since the promises of financial support for participants had to be delayed considerably. Thanks to the remarkable degree of understanding, cooperation and trust shown by the programme organizers as well as the prospective participants all the major programmes scheduled for 2011 could actually take place very successfully and with not too many cut-backs. From February 1 to April 22 M. Aguiar, F. Lehner, R. Speicher, and D. Voiculescu organized a programme on *Bialgebras in free Probability* with special workshops on *Combinatorial, Bialgebra, and Analytical Aspects* and *Random Matrix, Operator Algebra, and Mathematical Physics Aspects* in February and April, respectively.

During the months April–June 2011 A. Constantin, J. Escher, D. Lannes, and W. Strauss organized a programme on *Nonlinear Water Waves* with workshops on *Qualitative and Numerical Aspects of Water Waves and Other Interface Problems* (May 17–19) and on *Surface Water Waves* (May 3–June 1). The cataclysmic events at Fukushima just before the beginning of this programme provided a tragic backdrop to these activities at the ESI.

By the end of May 2011 the financial and administrative details of the transition of the ESI from an independent research institute to a 'Forschungsplattform' at the University of Vienna had been finalized, and Klaus Schmidt, who had been responsible for the running of the 'old' ESI, handed over business and responsibility to Joachim Schwermer, the Director of the 'new' ESI.

On September 21, 2011, the RESTART of the ESI in its new incarnation was celebrated officially. In his opening address the Rector of the University of Vienna Professor Georg Winckler said "We are delighted that we were able to deepen the already existing relationships between the researchers of the University of Vienna and ESI." He continued, in view of the new organizational structure of the ESI as a research centre, "Our aim is to provide outstanding scientists from the disciplines of mathematics and physics with a forum to exchange ideas and to network. The visibility of the University of Vienna and the performance of its researchers are to be strengthened through ESI". As a highlight of the restart Fields medalist Wendelin Werner (University Paris-Sud, Orsay) gave a lecture on *Random surfaces and their geometry*, addressing questions in a current field of research important for both mathematics and mathematical physics.

Thanks to the ongoing efforts of the University Administration, the old and new leadership of the ESI, and the organizers of the planned thematic programmes, all activities of the ESI during the second half of 2011 could take place as planned. The following list gives an impression of the range of scientific activities of the Institute during that half year.

I THEMATIC PROGRAMMES

- *Dynamics of General Relativity: Numerical and Analytical Approaches* (organized by L. Andersson, R. Beig, M. Heinzle, S. Husa) July 4 - September 2, 2011,
- *Combinatorics, Number theory, and Dynamical Systems* (organized by M. Einsiedler, P. Grabner, C. Krattenthaler, T. Ziegler) October 1 - November 30, 2011, which included the workshops "*Dynamics and Number Theory*", October 10 - 14, and "*Dynamics and Combinatorics*", November 14 - 18.

II Workshops

- *Topological Heterotic Strings and (0,2) Mirror Symmetry* (organized by J. Distler, J. Knapp, M. Kreuzer , I. Melnikov), June 20 - 24, 2011.
- *Memorial Conference for Maximilian Kreuzer* (organized by Ludmil Katzarkov, J. Knapp, A. Rebhan, E. Scheidegger) June 25 - 28, 2011.
- *ESF-EMS-ERCOM Conference "Completely Integrable Systems and Applications"* (organized by G. Teschl), July 3 - 8, 2011.
- *Cartan connections, geometry of homogeneous spaces, and dynamics* (organized by A. Cap, C. Frances, K. Melnick) July 10 - 23, 2011.
- *Summer School in Mathematical Physics* (organized by C. Hainzl, R. Seiringer), August 16 - 24, 2011.
- *Rigorous Quantum Field Theory in the LHC Era* (organized by C. Jäkel, C. Kopper, G. Lechner), September 20 - October 1, 2011.
- *Algebraic versus Analytic Geometry* (organized by H. Hauser, J. Kollar, J. Schicho, D. van Straten) November 19 - December 13, 2011, which included the special weeks: [1]: *Artin Approximation and Arcs*, [2]: *Local Analytic Geometry* [3] *: Minimal Model Program*
- *Infinite Monster Groups* (organized by G. Arzhantseva, M. Sapir), December 12 - 21, 2011.

In its Senior Research Fellows Programme the ESI offered the lecture course *L-functions and Functoriality* by James W. Cogdell (Ohio State University, Columbus, USA) for graduate students and postdocs in the fall term 2011. Our thanks go to him that, on short notice, he had agreed to spend his sabbatical at the ESI in Vienna.

The ESI continues to publish the ESI Lectures in Mathematics and Physics in cooperation with the European Mathematical Society. In 2011 the volume *Noncommutative Geometry and Physics: Renormalisation, Motives, Index theory*, edited by Alan Carey, appeared. A volume which contains the proceedings of the ESI Symposium "Erwin Schrödinger-50 years after" (Vienna, January 2011) is in preparation, edited by J. Yngvason and W. Reiter.

At this point we would like to draw your attention to a new component within the frame work of the scientific activities of the ESI, namely, the *Erwin Schrödinger Institute Research in Teams Programme*. It offers teams of 2 to 4 *Erwin Schrödinger Institute Scholars* the opportunity to work at the Erwin Schrödinger Institute in Vienna for periods of 1 to 4 months, in order to concentrate on new collaborative research in mathematics and mathematical physics. The interaction between the team members is a central component of this programme. The Erwin Schrödinger Institute Research in Teams Programme started January 2012. The first scholars within this programme will be at the ESI in June 2012.

Finally we would like to thank the administrative staff – Alexandra Katzer, Isabella Janger and Beatrix Wolf – for their unfailing friendly and efficient work and their good humour towards our visitors, research fellows and scientific staff of the Institute, even during the difficult months when the Institute was acutely threatened with closure.

Klaus Schmidt
President of the Foundation ESI
[Head of the ESI until May 31, 2011]

Joachim Schwermer
Director ESI
[since June 1, 2011]

Vienna, April 18, 2012

The ESI in 2011

Management of the Institute

Honorary President of the Foundation ESI: Walter Thirring

President of the Foundation, and head of ESI until May 31, 2011: Klaus Schmidt

Scientific Directors until May 31, 2011: Joachim Schwermer and Jakob Yngvason

Kollegium of the Research Center ESI since June 1, 2011: Joachim Schwermer (ESI Director), Goulnara Arzhantseva (Deputy Director), Jakob Yngvason (Deputy Director), Adrian Constantin, Piotr T. Chruściel, Frank Verstraete

Administration: Isabella Janger, Alexandra Katzer, Maria Marouschek (on maternity leave), Beatrix Wolf

Computers: Andreas Čap, Hermann Schichl, Gerald Teschl

International Scientific Advisory Committee

John Cardy (Oxford)
Edward Frenkel (Berkeley)
Nigel Hitchin (Oxford)
Horst Knörrer (Zürich)
Herbert Spohn (München)
Michael Struwe (ETH Zürich)
Vincent Rivasseau (Orsay)

Budget and visitors: In 2011 the support of ESI from the Austrian Federal Ministry of Science and Research from January 1 to May 31, 2011 was €329.167,–. The support of ESI from June 1 to December 31, 2011 was received via the University of Vienna from the Austrian Federal Ministry of Science and Research. The amount was EUR 460.833,– and EUR 22.000,– from the University of Vienna. The total spending on scientific activities in the year 2011 was EUR 389.503,38 and on administration and infrastructure EUR 395.586,27.

The number of scientists visiting the Erwin Schrödinger Institute in 2011 was 776, and the number of preprints was 50.

Scientific Reports

Main Research Programmes

Bialgebras in free Probability

Organizers: M. Aguiar (A & M Texas), M. Lehner (TU Graz), R. Speicher (Universität des Saarlandes), P. Voiculescu (UC Berkeley),

Dates: February 1 - April 22, 2011

Budget: ESI €47.741,–

Preprints contributed: [2313], [2318], [2320], [2327], [2329]

Report on the programme

Introduction

Free probability theory is a line of research that parallels aspects of classical probability in a highly non-commutative context where tensor products are replaced by free products and independent random variables are replaced by free random variables. It grew out from attempts to solve some longstanding problems about von Neumann algebras of free groups. In the almost twenty-five years since its creation, free probability has become a subject in its own right, with connections to several other parts of mathematics: operator algebras, the theory of random matrices, classical probability and the theory of large deviations, algebraic combinatorics.

In recent years, several bialgebra structures have occurred, in quite different ways, at a fundamental level in free probability theory, and it is becoming clear that progress in the field requires a better understanding of this phenomenon. Three instances stand out at this time: the connections to "combinatorial Hopf algebra", to bialgebras with derivation comultiplications (also known as "infinitesimal bialgebras"), and to the symmetries provided by certain "free" C^*-algebraic quantum groups. Up to our workshop there had been no closer interaction between researchers working in these different fields and one of the main goals of the ESI-programme was to provide an opportunity for such an interaction. The core groups of free probabilists and combinatorialists were supplemented by researchers from fields which connect to the above, most notably, operator algebras, random matrices, and mathematical physics.

Activities

The core activities of the ESI programme consisted of two workshops, each of two weeks duration. The first workshop had its emphasis on the combinatorial and stochastic aspects, whereas the second one emphasised operator algebraic and random matrix aspects. Since the participants came from very different backgrounds, introductions to the basic results and problems

of the respective topics were provided through four lecture series, each consisting of four 60 minutes lectures. The first two such series – on "Combinatorial Aspects of Free Probability" (by R. Speicher) and on "Infinitesimal Bialgebras" (by M. Aguiar) – were given during the first workshop, whereas the other two – on "Probabilistic Aspects of Free Quantum Groups" (by T. Banica) and "Around the Free Riemann Sphere and Duality for Infinitesimal Bialgebras" (by D. Voiculescu) – were given during the second workshop. Between the workshops we had a couple of long term visitors and several seminar talks and informal discussion sessions. Parallel to this there was also running a lecture series on Free Probability Theory in the Senior Fellow Lectureship programme, consisting of two lectures and one seminar per week. The first half of this lecture series was given by K. Dykema, the second half by R. Speicher. Those lectures were attended by faculty and students from the University of Vienna as well as from participants of the ESI programme.

As special general highlight we want to emphasize the high quality of the workshop talks. Aimed at an audience with very different backgrounds, most of them succeeded in giving not only a general flavour of the presented subject, but also in presenting very precise problems and concrete solutions. Another outstanding feature of the programme was the participation of many young people. It became apparent that the subjects of free probability, Hopf algebras, random matrices, and operator algebras are vibrant and flourishing, where young people can and do make important contributions. In addition to the regular workshop talks of 50 minutes length (where we already had many speakers on a postdoc and even some on a graduate student level) we also asked some of the attending PhD students (like Alekseev, Arizmendi, Blitvic, Brannan, Cheballah, Male, Redelmeier, Sattlecker, Vargas, Williams) to present their work in 30 minutes talks. The quality of those talks and of the presented results is very promising for the future of the subject.

The very lively discussions at the blackboards in the halls of ESI were a genuine testimony of the success of the programme. Many of the participants met for the first time at ESI and realized the wide range of connections between their own subject and other, a priori quite different, fields.

Specific information on the programme

(i) Combinatorial Hopf algebras and operations on free random variables

Ordinary moments and cumulants of classical random variables are related through the combinatorics of set partitions. This is in turn modeled by the Hopf algebra of symmetric functions, which constitutes the prototype of a large class of "combinatorial" Hopf algebras, an area in which there has been profuse activity in recent years. The topic of symmetric functions is classical. There are connections with enumerative combinatorics, the representation theory of symmetric and general linear groups, and the geometry of flag manifolds, among others. The combinatorics that relates free moments and free cumulants of non-commutative random variables is that of non-crossing partitions. The Hopf algebraic aspects of this relation are only recently beginning to be understood.

This subject was one of the main topics of the first workshop. Introductory lectures on the combinatorial structure of free probability were given by R. Speicher. The participation of various researchers specialized in the combinatorial theory of Hopf algebras (like Aguiar, Brouder, Krattenthaler, Loday, Mazza, Patras) provided a unique opportunity for a deeper interaction between the free probability and the Hopf algebras communities.

As a concrete example of the connection between Hopf algebras and free probability we mention the talk of Mastnak on recent results by Nica and Mastnak. They show how one can use combinatorial Hopf algebras to describe the multiplication of free random variables and give an alternative approach to the S-transform (the analogue of the Mellin transform).

(ii) The noncommutative analysis of the free difference quotient derivations and infinitesimal bialgebras (GDQ rings)

For variables with the highest degree of noncommutativity, like those occurring in free probability, the natural derivations are the free difference quotient derivations. The free difference quotient derivation turns out to be the comultiplication of a bialgebra from the class of "infinitesimal bialgebras". This class of bialgebras, like the class of Hopf algebras is selfdual and the associated duality transform (which would play the role of the Fourier transform) turns out to be a highly noncommutative extension of the Stieltjes transform. This bialgebra duality has produced a conceptual approach and extension of the analytic subordination results in free probability and was motivated also by free entropy (the analogue of Shannon's continuous entropy) and the connection to random matrix theory.

This subject featured prominently in both workshops. Introductions to infinitesimal bialgebras and to noncommutative analysis of the free difference quotient derivations were given in the lectures series by Aguiar and by Voiculescu, respectively. It is worthwhile to point out that in the talks of Aguiar the analytic approach of Voiculescu was presented, for the first time, from a much more algebraic perspective.

(iii) "Free" C^*-algebraic quantum groups and noncommutative de Finetti theorem

In the last ten years or so there has been a surge of results around special classes of quantum groups, most notably by Banica and his collaborators. It has turned out that canonical quantum group versions (in the sense of Woronowicz) of classical compact groups have a very rich structure and are intimately related with free probability theory. A recent new development in this direction is a de Finetti type result of Köstler and Speicher, which shows that invariance under the quantum permutation group characterizes freeness. This makes the case both for free quantum groups in free probability and for free probability in noncommutative extensions of the de Finetti theorem. Further work on quantum group invariance needs to be done in various situations. In particular, the occurrence of such quantum invariants in the context of planar algebras and operator spaces, but also in various physical situations.

This subject was mainly presented in the second workshop, where leading experts on these topics were present at ESI (Junge, Shlyakhtenko, Vergnioux, Woronowicz, Zinn-Justin). An introductory lecture series on free quantum groups was given by T. Banica.

(iv) Large N-limit of random multi-matrix systems, von Neumann algebras and free probability

An important aspect of free probability is its relation with the theory of random matrices in the large N limit. Free probability provides rigorous concepts for dealing with this limit and thus promises to give a sound basis and allows generalizations of many results which have been derived in a non-rigorous way in physics. An important object in this context is the so-called Schwinger-Dyson (or loop) equation, which should describe the limit of random matrix models. The nature of this equation is very combinatorial and related with cyclic derivatives and the free difference quotient. Moreover this equation is also the critical point equation for a variational problem for free entropy. Whereas for one-matrix models this equation and its solution are well understood and rigorously established, the situation for several matrices is still unclear, even on a physical level. Guionnet and coworkers have made some important progress on these questions, relying on ideas and results from free probability and graph theory. Also, the free probability aspect of the large N-limit of random multi-matrix systems has had important applications to von Neumann algebras of free groups. A recent important advance in this vein has found connections to the planar algebra approach to subfactors.

This subject was one of the main topics of the second workshop, with the presence of many random matrix experts. Again we had a wide distribution of participants, ranging from pure mathematics over physics to very applied fields, like wireless communication. One example of the breadth of the programme and of reaching out into combinatorial aspects of mathematical physics was the attendance of Di Francesco and his excellent talk about his recent proof of the ASM-DPP Conjecture. As a highlight on the pure mathematical side, we want to mention the talk of Dabrowski as an example of the use of strong noncommutative analytic techniques, emerging from free probability, in the von Neumann algebra context.

Invited scientists: Nikita Alexeev, Michael Anshelevich, Marcelo Aguiar, Octavio Arizmendi, Teodor Banica, Serban Belinschi, Florent Benaych-Georges, Hari Bercovici, Philippe Biane, Natasha Blitvic, Marek Bozejko, Michael Brannan, Christian Brouder, Thierry Cabanal-Duvillard, Elisabetta Candellero, Mireille Capitaine, Gennadiy Chistyakov, Hayat Cheballah, Marie Choda, Benoit Collins, Stephen Curran, Agnieszka Czyzewska, Yoann Dabrowski, Nizar Demni, Philippe Di Francesco, Maciej Dolega, Catherine Donati-Martin, Kenneth Dykema, Richard Ehrenborg, David Evans, Valentin Feray, Uwe Franz, Terry Gannon, Lorenz Gilch, Friedrich Goetze, Antti Harju, Michael Hartglass, Takahiro Hasebe, Fumio Hiai, Lech Jankowski, Matthieu Josuat-Verges, Marius Junge, K. Grace Kennedy, Claus Koestler, Christian Krattenthaler, Ilona Krolak, Franz Lehner, Romuald Lenczewski, Weihua Liu, Jean-Louis Loday, Tobias Mai, Hans Maassen, Jennifer Maier, Camille Male, Mitja Mastnak, Christian Mazza, Adam B. Merberg, James Mingo, Isak Wulff Mottelson, Naofumi Muraki, Alexandru Nica, Maciej Nowak, Leonid Pastur, Frederic Patras, Denes Petz, Mihai Popa, Mathew Pugh, Gerhard Racher, Florin Radulescu, Emily Redelmeier, Ecaterina Sava, William R. Schmitt, Christian Sattlecker, Claire Shelly, Dimitri Shlyakthenko, Piotr Sniady, Piotr Soltan, Roland Speicher, Alexander Tikhomirov, Steen Thorbjornsen, Gabriel Tucci, Yoshimichi Ueda, Carlos Vargas, Roland Vergnioux, Dan-Virgil Voiculsecu, John David Williams, Jiun-Chau Wang, Moritz Weber, Stanislaw Woronowicz, Feng Xu, Makato Yamashita, Paul Zinn-Justin, Piotr Zwiernik.

Nonlinear Water Waves

Organizers: A. Constantin (Vienna), J. Escher (Leibniz University, Hannover), D. Lannes (École Normale Supérieur, Paris), W. Strauss (Brown University, Providence)

Dates: April 4 - June 30, 2011

Budget: ESI €43.692,–

Preprints contributed: [2316], [2335]

Report on the programme

Scientific scope. Water waves lie at the forefront of modern mathematics and mathematical physics, and the study of water wave phenomena has been a rich source of deep mathematical theories for over 200 years. Also, mathematics is essential in seeking to understand this fascinating field of physical reality and adds immensely to the enjoyment obtained from the observation of the wealth of water wave phenomena nature confronts us with. The aim of the programme was to concentrate both on classical topics as well as on topics where some new developments are taking place and which have been not so well represented in recent workshops or other larger scientific gatherings.

Participation. The participation was international and interdisciplinary. Researchers from the following countries (18 in total) participated actively in the program: Austria, Brazil, Bulgaria, Canada, P. R. China, France, Germany, Ireland, Israel, Italy, Norway, Romania, Spain, Sweden, Switzerland, Taiwan, United Kingdom, USA. Four researchers stayed for the full period, six

opted for a long stay (4-8 weeks each), sixteen researchers stayed about two weeks and sixteen others visited for about one week (on the occasion of one of the two workshops). Among the visiting researchers 5 were women: three established researchers (Prof. E. Kartashova from Linz, Prof. C. Sulem from Toronto, Dr. Vera Hur from Urbana-Champaign) and two Ph.D.-students (A. Geyer from Vienna and A.-V. Matioc from Hannover). As for the interdisciplinary character, while most of the visiting researchers were analysts, some leading experts in numerical analysis (Prof. J.-M. Vanden-Broeck from London, Prof. D. Clamond from Nice, Prof. A. Nachbin from Rio de Janeiro) also participated in the program. The scientific scope was widened due to the presence of several visitors working in engineering, both in theoretical (e.g. Prof. M. Stiassnie from Haifa) as well as in experimental (e.g. Prof. M. Umeyama from Tokyo and Dr. H. Hsu from Tainan) directions.

Special events. Two workshops took place during the programme:

- "Workshop on qualitative and numerical aspects of water waves and other interface problems", May 17 - 19, 2011 (17 talks);
- "Workshop on surface water waves", May 31 - June 1, 2011 (8 talks).

Also, a popular lecture on tsunamis (with speaker Prof. H. Segur from Boulder) and a discussion group (aimed at facilitating the communication between theoretical researchers and experimentalists) were organized.

Main topics. To describe the main topics of the programme, we group the talks according to their content. The topics are not disjoint, being in many respects closely related.

1. *Free surface water waves.* These are among the first and still most important free surface problems in mathematics. They are governed by partial differential equations inside the fluid with integral or pseudodifferential equations which describe the free surface. They are intrinsically nonlinear. Germain presented a recent breaktrough result on the existence of global solutions to the governing equations for gravity water waves in three spatial dimensions. Aspects of wave propagation in water regions over a bed whose topography is characterized by strong variations were covered by Sulem and Nachbin. Gavrilyuk presented a model for sheared shallow water flows. Recent results on the existence of travelling water waves at the surface of flows with stagnation points were discussed in the talks of A. Matioc and Varvaruca, while Strauss presented an approach towards the investigation of flows with discontinuous vorticity. Variational approaches towards the understanding of vorticity effects on water waves were discussed by Burton. The regularity of the free surface and of the streamlines in wave-current interactions was the object of presentations by Escher and B. Matioc. Ionescu-Kruse showed a theoretical approach towards the flow beneath a wave, while Clamond and Umeyama presented numerical and experimental results, respectively. The numerical simulation of water waves was also the object of the presentation by Vanden-Broeck. Kartashova talked about the formation of energy cascades in turbulent water-wave systems.

2. *Stability theory of fluids.* The stability theory requires two separate kinds of analysis: one on the linearized system and one on the passage from linear to nonlinear. Both of these analyses have recently enjoyed major advances in the rigorous mathematical theory. Lannes presented a recent breaktrough concerning the stability of two-fluid interfaces, covering the linear and weakly nonlinear regimes. Wahlen discussed the stabilizing effect of surface tension on solitary water waves, and Grunert presented recent results on the nonlinear stability of solutions to a nonlinear model for shallow water waves. Holden's

talk emphasized the importance of a variational structure. The presentation by Groves dealt with the stability of fully localized three-dimensional gravity-capillary solitary water waves.

3. *Aspects of integrable systems and solitons.* Recently considerable insights into the dynamics of waves of moderate amplitude were obtained by in-depth studies of some nonlinear integrable model equations. This theory extends the classical results on waves of small amplitude (a development in which the Korteweg-de Vries equations occupies a prominent role) and confronts the research community with new phenomena, the most striking one being that of breaking waves. Sharp well-posedness results for KdV-type equations were presented by Kano and Molinet, while Saut discussed the Cauchy problem for Boussinesq systems. Gerdjikov discussed the modelling the soliton interactions of the nonlinear Schrödinger equation, while Ivanov dealt with integrable models arising in the study of wave-current interactions and Euler highlighted some recent approaches dealing with integrals of motion for equations that are small perturbations of integrable systems. The talks of Kolev and Wunsch covered some modern geometric aspects of integrable equations of hydrodynamic type. Totz presented some recent results on the rigorous justification of the modulation approximation to the 2D full water-wave problem.

4. *Tsunami waves.* These devastating manifestations of nature occur relatively seldom but over the last years two tsunamis with an unimaginable destructive effect were recorded — the December 2004 tsunami initiated in Sumatra and the 2011 Japan tsunami. Segur's talk offered a survey of the challenges in understanding the wave dynamics in these two recent tsunami events, while Johnson presented an approach to model the propagation of tsunami waves in the open sea. Mustafa's talk addressed the issue of isolated vorticity regions beneath the water surface (of relevance to tsunami waves encountering a current). Iguchi presented an in-depth mathematical analysis of tsunami generation in shallow water due to seabed deformation and Stiassnie's talk offered some calculations on tsunamis relevant for the Mediterannean basin.

Scientific output. The excellent conditions for research (either individually or in collaboration) offered by ESI were appreciated by all participants. A selected number of research papers (12 in total) that were practically an outcome of the participation in the programme will appear in the special issue "Nonlinear Water Waves" of the *Phil. Trans. Roy. Soc. London* (in print). The content of all these papers was presented in seminars during the programme.

Invited Scientists: Alexandru Aleman, Christer Bennewitz, Boris Buffoni, Didier Clamond, Adrian Constantin, Peter de Boeck, Vincent Duchenne, Mats Ehrenström, Joachim Escher, Norbert Euler, Marianna Euler, A. S. Fokas, Armengol Gasull, Vladimir Gerdjikov, Pierre Germain, Ionel-Dumitrel Ghiba, Georgi Grahovski, Mark Groves, Philippe Guyenne, David Henry, Helge Holden, Hungchu Hsu, Vera Mikyoung Hur, Tatsuo Iguchi, Delia Ionescu-Kruse, Rossen Ivanov, Robin Johnson, Russel Johnson, Tadayoshi Kano, Elena Kartaschova, Boris Kolev, David Lannes, Yue Liu, ony Lyons, Fabien Marche, Anca Matioc, Bogdan Matioc, Anders Melin, Luc Molinet, Octavian Mustafa, Andrei Nachbin, Dmitry Pelinovsky, Jean-Claude Saut, Harvey Segur, Michael Stiassnie, Walter Strauss, Catherine Sulem, Nathan Totz, Motohiko Umeyama, Jean-Marc Vanden-Broeck, Eugen Varvaruca, Gabriele Villari, Erik Wahlen, Marcus Wunsch, Luca Zampogni, Arghir Zarnescu, Zhaoyang Yin.

Dynamics of General Relativity: Numerical and Analytical Approaches

Organizers: L. Andersson (MPI Potsdam), R. Beig (Vienna), M. Heinzle (Vienna), S. Husa (Mallorca)

Dates: July 4 - September 22, 2011

Budget: ESI €43.540,– ; Stadt Wien €2.000,–

Preprints contributed: [2305], [2307], [2328], [2330], [2332], [2345], [2346], [2351]

Report on the programme

The programme "Dynamics of General Relativity" was devoted to numerical and analytical aspects of General Relativity and their interaction. Not including local participants (approx. 15), the programme was attended by 40 scientists, the majority of whom reported on their research in formal talks. The main activities of the programme can be grouped into the (overlapping) areas:

Black hole initial data. An basic open problem in the study of black holes is the construction of "high quality" initial data for black hole binaries, in particular for highly spinning black holes, which are quite likely to exist in nature. This means for example that initial data should have minimal amounts of physically unrealistic gravitational wave content. A fruitful new approach that has been worked on by a number of workshop participants (Husa, Hannam, Ó Murchadha, Beig) are asymptotically cylindrical (or "trumpet") initial data. A particular issue in this context that has been discussed at the workshop is the construction of Kerr and general binary black hole trumpet data, e.g., in the form of a constant mean curvature slice. Progress in describing initial data of black holes will also facilitate the development of improved numerical methods of evolving black hole spacetimes.

Numerical evolution of black holes. The numerical evolution of black holes requires high precision numerical calculations, a subject that is also attracting interest from mathematicians working in numerical analysis (Zumbusch, Lau). New numerical approaches for black hole evolution that have been discussed at the workshop are spectral element methods, discontinous Galerkin methods, and IMEX methods (Hannam, Lau, Zumbusch, Pürrer). A project to compare methods and results from two of the leading collaborations in the field of binary black hole evolution has been initiated at the workshop (Husa, Hannam, Pfeiffer, Pürrer).

The formation of black holes from regular initial data, whose past is geodesically complete, is another important subject which has been studied by a combination of numerical and analytical techniques (Andréasson).

A further problem in the numerical evolution of black holes is to accurately and unambiguously describe gravitational waves generated by black holes. This links to the topic of "spacetime asymptotics".

Spacetime asymptotics. Towards the problem of describing the gravitational waves output at future null infinity of an asymptotically Minkowskian spacetime, there are two main approaches, which have attracted a lot of interest in the programme: The characteristic (Pollney, Bishop, Reisswig) and hyperboloidal (Sarbach, Pfeiffer, Moncrief, Husa) initial value problem.

Possible asymptotic conditions describing the weak field regime that have being studied at the workshop are asymptotically Minkowskian (Friedrich, Moncrief), de Sitter (Ringström), and anti-de Sitter. The latter is a hot topic both in the context of the AdS/CFT correspondence (Landsteiner) and classical general relativity. Recent results provide strong evidence against the stability of the anti-de Sitter spacetime with possibly broad ramifications (Bizoń, Rostworowski, Jalmuzna).

Nonlinear stability of spacetimes. The numerical approaches to the (in)stability of anti-de Sitter spacetime (Bizoń et al.) have been complemented by mathematical studies of the stability of black hole spacetimes. A important problem in this context is to obtain sharp decay estimates

for linear fields propagating on black hole spacetimes (Dafermos, Holzegel, Andersson, Blue). The geometric characterization of black hole spacetimes (Valiente-Kroon, Bäckdahl, Garcia-Parrado) provides additional tools in this field of study.

Dynamics of cosmological models. In the evolution of spacetimes that develop a generic spacelike singularity, according to the BKL scenario, the role of spatial inhomogeneities should be dynamically irrelevant (Calogero, Heinzle, Uggla). However, in the approach to the singularity, spatial structures ("spikes") can form (recurrently) also on subhorizon scales. The investigation of these structures is an important step toward understanding strong cosmic censorship (Uggla, Lim, Heinzle, Ringström). In the broader context of the cosmic censorship conjecture, work on pointwise estimates of solutions to the Einstein equations (Moncrief, LeFloch) and weak solutions (LeFloch, Beig, Gundlach) is hoped to ultimately play a role.

Invited Scientists: Peter C. Aichelburg, Steffen Aksteiner, Artur C. F. Alho, Lars Andersson, Hakan Andreasson, Thomas Bäckdahl, Robert Beig, Eloisa Bentivegna, Nigel Bishop, Piotr Bizoń, Pieter Blue, Carles Bona, Simone Calogero, Otis Chodosh, Matt Choptuik, Yvonne Choquet-Bruhat, Piotr Chrusciel, Mihalis Dafermos, Sergio Dain, Roland Donninger, Michael Eichmair, David Fajman,. Helmut Friedrich, Maria Gabach-Clement, Greg Galloway, Alfonso Garcia-Parrado, James Grant, Nishanth Gudapati, Carsten Gundlach, Ingomar W. Gutmann, Mark Hannam, Mark Heinzle, Jan Hesthaven, David Hilditch, Michael Holst, Gustav Holzegel, Sascha Husa, Jim Isenberg, Jose-Luis Jaramillo, Joanna Jalmuzna, Jeremie Joudioux, Mikolaj Korzynski, Gergely Kovacs, Joachim Krieger, Stephen Lau, Karl Landsteiner, Philippe LeFloch, Woei-Chet Lim, Hans Lindblad, Maciej Maliborski, Marc Mars, Vincent Moncrief, Luc Nguyen, Frank Ohme, Niall Ó Murchadha, Tim-Torben Paetz, Harald Pfeiffer, Herbert Pfister, Denis Pollney, Michael Pfürrer, Istvan Racz, Martin Reiris, Christian Reisswig, Hans Ringström, Andrzej Rostworowski, Milton Ruiz, Olivier Sarbach, Patricia Schmidt, Walter Simon, Jacques Smulevici, Evgeny Sorkin, Claes Uggla, Juan Valiente Kroon, Alex Vano-Vinuales, Gerhard Zumbusch.

Combinatorics, Number Theory, and Dynamical Systems

Organizers: M. Einsiedler (Zürich), P. Grabner (Graz), C. Krattenthaler (Vienna), T. Ziegler (Haifa)

Dates: October 1 - November 30, 2011

Budget: ESI €52.000,–

Preprints contributed: [2341], [2342]

Report on the programme

The programme "Combinatorics, Number theory, and Dynamical Systems" was devoted to the interplay between dynamical systems, number theory, and (especially) infinite combinatorics. It culminated in two workshops on "Dynamics and Number Theory" (October 10–14) and on "Dynamics and Combinatorics" (November 14–18).

The programme was attended by 63 participants, mostly present during and around the workshops. At the workshops lecture series on recent progress as well as contributed talks by participants were presented. In total 35 talks were presented. Beside the lecture programme there was enough time for scientific discussion and personal interaction.

Below we briefly describe some highlights of the programme of the workshops:

Workshop on "Dynamics and Number Theory"

Lecture series. A. Gorodnik gave a series of lectures on selected techniques from homogeneous dynamics that were used in recent number-theoretic applications. He explained an approach to questions in Diophantine approximation based on the study of extreme values of flows and an approach to counting integral/rational points on varieties based on the study of the distribution of orbits. A crucial role in many of these developments was played by the spectral gap property and its various refinements such as exponential mixing and quantitative ergodic theorems.

J. Marklof in his lecture series discussed a number of classical and not-so-classical equidistribution problems in the space of lattices and some of their applications in number theory, combinatorics, and mathematical physics. The focus was on the distribution of sublattices, Hecke points and Farey fractions embedded in horospheres. The applications included: diameters of random Cayley graphs, the asymptotic distribution of Frobenius numbers, statistics of visible lattice points, and randomness in the distribution of certain number-theoretic sequences modulo 1.

Diophantine approximation. B. Adamczewski gave a talk about tools from symbolic dynamics, combinatorics on words and Diophantine analysis in the study of the combinatorial complexity of digital expansions of constants like $\sqrt{2}$, e, and π. Y. Bugeaud gave a survey on recent results on the continued fraction expansion of algebraic numbers of degree at least three. A striking result is that the infinite word composed of the partial quotients of an algebraic number of degree at least three cannot have sublinear block complexity and thus cannot be generated by a finite automaton.

Invariant measures. E. Lindenstrauss presented joint work with M. Einsiedler on classifying invariant and ergodic probability measures on arithmetic homogeneous quotients of semisimple S-algebraic groups invariant under a maximal split torus in at least one simple local factor, and showed that the algebraic support of such a measure splits into the product of four homogeneous spaces: a torus, a homogeneous space on which the measure is (up to finite index) the Haar measure, a product of homogeneous spaces on each of which the action degenerates to a rank one action, and a homogeneous space in which every element of the action acts with zero entropy.

Thin groups and super strong approximation. A. Gamburd talked about a generalization of Selberg's 3/16 theorem and the affine sieve. He presented joint work with Bourgain and Sarnak, in which they establish a generalization of Selberg's theorem for "thin" (infinite index) "congruence" subgroups of $\mathrm{SL}(2,\mathbb{Z})$, and discussed applications to the affine sieve.

Effective equidistribution. A. Strömbergsson presented a result giving effective equidistribution of (1-dimensional) unipotent orbits in $\mathrm{ASL}(2,\mathbb{Z})\backslash\mathrm{ASL}(2,\mathbb{R})$, where $\mathrm{ASL}(2,\mathbb{R})$ is the affine special linear group of order 2. The proof involves spectral analysis and use of Weil's bound on Kloosterman sums. A. Ubis talked about an effective version of Dani's theorem and applications to equidistribution of prime orbits.

Measure rigidity. A. Katok reported on recent progress in the "non-uniform measure rigidity" programme started in 2007 and pursued in collaboration with B. Kalinin and F. Rodriguez Hertz.

Workshop on "Dynamics and Combinatorics"

Lecture series. C. Mauduit and J. Rivat presented their recent solution of two problems by A. O. Gel'fond on the distribution of the sum-of-digits function of primes and squares. Let q be an integer greater or equal to 2. These lectures concerned the study of some q-additive properties of prime and polynomial numbers. It was shown that such combinatorial number

theory questions are linked to the study of some symbolic dynamical systems and to the precise estimates of certain Fourier transforms. The first lecture gave a survey on results concerning the representation of prime and square numbers in base q. The second lecture presented a strategy to solve Gel'fond's problem concerning the distribution in arithmetic progressions of the sum of digits of prime numbers, and discussed the extension of this result to more general q-additive problems. The third lecture presented more recent results on Gel'fond's problem concerning the distribution in arithmetic progressions of the sum of digits of polynomial numbers and several related open questions.

Infinite combinatorics. V. Bergelson discussed the role of ultrafilters in partition Ramsey theory, and surveyed some recent applications of ultrafilters in the theory of multiple recurrence. These included an extension of the polynomial Szemerédi's theorem and some new results on polynomial actions of unitary operators. N. Frantzikinakis presented new results on Szemerédi's theorem for multiple recurrence along Hardy sequences. M. Walsh described his proof of norm convergence of nilpotent multiples ergodic averages.

Diophantine approximation. A. Ghosh discussed joint work with A. Gorodnik and A. Nevo on analogues of the classical theorems of Khintchine and Jarník in the context of homogeneous varieties of semisimple algebraic groups.

Ergodic theory and additive combinatorics. A. Fish talked about joint wok with M. Björklund on Plunnecke inequalities for sumsets in the context of ergodic dynamical systems. As an application they showed a sumset theorem for subsets of countable amenable groups. M. Björklund described product set theorems for countable amenable groups via ergodic theory and topological dynamics, and discussed connections to some unsolved conjectures on Bohr regularity.

Algebraic $\mathbb{Z}^d$-actions. K. Schmidt presented new results on the entropy of algebraic $\mathbb{Z}^d$-actions. For certain $\mathbb{Z}^d$-actions by automorphisms of compact abelian groups entropy coincides with the upper limit of the logarithmic growth rate of the number of periodic points of the action. The question whether entropy is equal to the limit of this logarithmic growth rate is much more difficult and involves unresolved multi-dimensional diophantine problems.

H. Li presented relations of the entropy of $\mathbb{Z}^d$-actions with Fuglede-Kadison determinants.

Invited Scientists: Boris Adamczewski, Goulnara Arzhantseva, Michael Baake, Vitaly Bergelson, Michael Björklund, Alexander Bufetov, Yann Bugeaud, Christopher Deninger, Manfred Einsiedler, Alexander Fish, Nikos Frantzikinakis, Swiatoslaw Gal, Alexander Gamburd, Anish Ghosh, Alexander Gorodnik, Evgeny Goryachko, Peter Grabner, Jiyoung Han, Norbert Hegyvári, Michael Hochman, Shirali Kadyrov, Anatole Katok, Dmitry Kleinbock, Janne Kool, Christian Krattenthaler, Sanghoon Kwon, Jeff Lagarias, Hagai Lavner, Han Li, Seon-Hee Lim, Elon Lindenstrauss, Doug Lind, Beverly Lytle, Andrey Malyutin, Alex Maier, Jens Marklof, David Masser, Christian Mauduit, Shahar Mozes, Radhakrishnan Nair, Arnaldo Nogueira, Hee Oh, Alina Ostafe, Fedor Petrov, Anke Pohl, David Ralston, Felipe Ramirez, Joël Rivat, Imre Ruzsa, Oliver Sargent, Klaus Schmidt, Uri Shapira, Matthew Staines, Andreas Strömbergsson, Adrián Ubis, Péter Varjú, Evgeny Verbitskiy, Jean-Louis Verger-Gaugry, Anatoly Vershik, Miguel Walsh, Thomas Ward, Barak Weiss, Benjamin Weiss, Julia Wolf, Tamar Ziegler

Workshops Organized Outside the Main Programmes

Harmonic and Complex Analysis and its Applications

Organizers: H. G. Feichtinger (Vienna)

Dates: January 10 - 12, 2011

Report on the programme

This workshop was part of the activities of the EU network "Harmonic and Complex Analysis and its Applications" and was entirely funded from the network budget. The programme, including abstracts of talks and a list of participants can be found on the website `http://www.univie.ac.at/nuhag-php/event_NEW/make.php?event=hcaa11`

Symposium: Erwin Schrödinger–50 years later

Organizers: C. Dellago (Vienna), W. L. Reiter (Vienna), J. Yngvason (Vienna), A. Zeilinger (Vienna); honorary chair: R. Braunizer (Alpbach)

Dates: January 13 - 15, 2011

Budget: ESI € 9.576,–

Report on the programme

The symposium commemorated Erwin Schrödinger's death on January 4, 1961, and was dedicated to his legacy in quantum theory and to his views on the interpretation of quantum mechanics from a contemporary perspective. A series of lectures outlined recent experimental and theoretical developments related to Schrdinger's work, as well as his influence from the point of view of history and philosophy of science.

The symposium was opened by the Rector of the University of Vienna, *G. Winckler* and began with a public evening lecture *(Wiener Vorlesung)*, organized in cooperation with the City of Vienna:
Jürgen Renn, MPI für Wissenschaftsgeschichte, Berlin: Schrödingers Weg zur Wellenmechanik

Other lectures at the Symposium were:

- *Walter Thirring*, University of Vienna and ESI: Erwin Schrödinger: Personal Reminiscences
- *Jürg Fröhlich*, ETH Zürich: A Minimalists View of Quantum Mechanics, Eighty Five Years After Schrödinger's 'Annus Mirabilis'
- *Anton Zeilinger*, University of Vienna and IQOQI, Vienna: The Career of Schrödinger's Entanglement from Philosophical Curiosity to Quantum Information
- *Peter Zoller*, University of Innsbruck: Digital and Open System Quantum Simulation with Trapped Ions
- *Roberto Car*, Princeton University: Quantum mechanics and hydrogen bonds
- *K. Birgitta Whaley*, University of California, Berkeley: Quantum Coherence and Entanglement in Biology

- *Moty Heiblum*, Weizman Institute of Science: Neutral Modes – A New Family of Energy Carrier Currentless States
- *Olivier Darrigol*, CNRS, Paris: A few Reasons why Louis de Broglie discovered Broglie's Waves and yet did not discover Schrdinger's Equation
- *Helge Kragh*, University of Aarhus: A Quantum Discontinuity: the Bohr-Schrödinger Dialogue

Proceedings of the symposium, edited by Wolfgang Reiter and Jakob Yngvason and containing most of the lectures as well as some further contributions, will be published in the ESI Lectures in Mathematics and Physics series.

Invited scientists: Markus Arndt, Ruth Braunizer, Michel Bitbol, Roberto Car, Olivier Darrigol, Christoph Dellago, Timothy Field, Jürg Fröhlich, Moty Heiblum, Helge Kragh, Wolfgang Reiter, Jürgen Renn, Klaus Schmidt, Joachim Schwermer, Walter Thirring, K. Brigitta Whaley, Jakob Yngvason, Anton Zeilinger, Peter Zoller.

Follow-up Workshop to the 2009 ESI Programme on "Selected Topics in Spectral Theory"

Organizer: B. Helffer (Paris), T. Hoffmann-Ostenhof (Vienna), A. Laptev (Stockholm)

Dates: January 17 - 27, 2011

Budget: ESI €12.701,– ; ESF €1.532,–

Report on the programme

This small workshop with about 25 participants was a follow up programme of the activity with the same title of 2009. A wide variety of topics from spectral theory was covered in the talks and the discussions. Many talks had a geometric flavour.

The quite new notion of minimal spectral partitions was considered in 5 talks. With the help of these minimal spectral partitions new relations between nodal domains and the spectrum have been established. In particular the case of equality in Courant's famous nodal theorem can be characterized by these minimal partitions. They emerge from a nonlinear variational problem. Helffer gave an instructive survey talk, numerical aspects were discussed in the talks by Bonnaillie-Noël and Vial. Terracini explained some new aspects of those problems in her talk. Related interesting problems and results about quantum graphs where presented in Berkolaiko's talk.

Quantum graphs have been also considered by Demirel. The notion of nodal domains played an important role in the talks by Smilansky, Kennedy and Frank. Frank considered nodal domains of eigenfunctions of fractional Laplacians, a circle of problems that is of increasing importance. Geisinger considered two-term spectral asymptotics also for fractional Laplacians.

The classical spectral problems for membranes and manifolds have been considered in the talks of Freitas, Iversen, van den Berg and El Soufi. Of course there are a lot of deep problems there starting from spectral asymptotics to the relation between the geometry of the domain or the manifold and the corresponding lowest eigenvalues.

Spectral problems for magnetic Schrödinger operators are interesting from a physics and geometrical point of view. Many aspects of those problems are still only poorly understood. Fournais

(problems stemming from Ginzburg Landau problems) and Kovarik gave instructive talks on such problems. Pushnitski dsicussed eigenvalue clusters of Landau Hamiltonians. Also in the survey talk of Helffer the relation between Aharonov-Bohm Hamiltonians and minimal partitions was explained.

There were some additional talks about various other spectral problems. Nam has obtained a substantial improvement of a classical result of Lieb concerning the maximal negative charge of an atom. Østergaard Sørensen has studied the interesting regularity questions for eigenfunctions of some non-linear relativistic models for atoms and molecules where nonlocal problems have to be treated. Inverse problems concerning Hankel operators and their relation to completely integrable systems have been discussed in an impressive talk by Patrick Gerard. Loss analyzed in his talk some spectral questions in relation with a random displacement model. Yafaev considered first order matrix operators and the exponential decay of their eigenfunctions. There is a relation with the usual case of second order Schrödenger operators, but some new phenomena can happen.

Invited scientists: Lior Aermark, Gregory Berkolaiko, Virginie Bonnaille-Noël, Semra Demirel, Tomas Ekholm, Ahmad El Soufi, Rupert Frank, Pedro Freitas, Leander Geisinger, Patrick Gerard, Bernard Helffer, Maria Hoffmann-Ostenhof, Thomas Hoffmann-Ostenhof, Mette Iversen, James Kennedy, Hynek Kovarik, Ari Laptev, Corentin Lena, Michael Loss, Phan Thanh Nam, Thomas Østergaard Sørensen, Alexander Pushnitski, Uzy Smilansky, Susanna Terracini, Michiel Van den Berg, Gregory Vial, Dimitri Yafaev.

Follow-up Workshop to the 2010 ESI Programme on "Quantitative Studies of Non-linear Wave Phenomena"

Organizers: P.C. Aichelburg (Vienna), P. Bizoń (Cracow)

Dates: January 24 - 29, 2011

Budget: ESI €4.880,–

Report on the programme

The main goal of this one-week meeting was to discuss the progress in projects that have been initiated during the workshop in February 2010. There were 15 participants (from Austria, Germany, Hungary, Ireland, Poland, and Spain). The discussions and seminars focused on the following topics:

Dynamics of wave maps. It is well known that wave maps in supercritical dimensions develop finite-time self-similar singularities, however until now little was known about the stability of blow-up. In recent work Birgit Schörkhuber, Roland Donninger, and Peter C. Aichelburg proved that for corotational wave maps from Minkowski space to the 3-sphere (the SU(2) sigma model), the blow-up described by the ground state self-similar solution is stable. The argument relies on a novel semigroup formulation of the linearized problem in adapted coordinates and the implicit function theorem on Banach spaces. This result was presented in talks by B. Schörkhuber and R. Donninger.

Einstein-Vlasov system. Alan Rendall presented the work done in collaboration with Juan Velazquez on the existence of self-similar solutions of the Einstein-Vlasov system. This is motivated by the wish to understand more about the formation of singularities in solutions of this system and the issue of cosmic censorship. By assuming a suitable ansatz, the existence problem is reduced to the construction of a particular kind of solution of a four-dimensional system of ODE, which can be solved by the shooting method.

Geometric heat flows. Piotr Bizoń and Pawel Biernat presented their joint work on singularity formation in the heat flow for harmonic maps into spheres. In this work they construct global weak solutions having the form of shrinking and expanding self-similar solutions glued together across a singularity. Surprisingly enough, it turns out that in the generic case such a weak solution is unique. Possible generalizations of this result were intensely discussed.

Saddle-point dynamics for wave equations. Nonlinear focusing wave equations typically exhibit dichotomy between blow-up and dispersion for small/large initial data. Two particular examples of this very interesting behavior were presented in the talks by Nikodem Szpak and Joanna Jalmużna. In both cases the critical solutions converge to unstable static solution and the saddle-point dynamics near this attractor is very sensitive to the spectral properties of the corresponding linear operator. The studies of these toy-models provide better analytic insight into critical phenomena for Einstein's equations.

Invited Scientists: Peter Aichelburg, Piotr Bizoń, Pawel Biernat, Piotr Chrusciel, Roland Donninger, Helmut Friedrich, Merse Elod Gaspar, Gergely Kovacs, Andras Laszlo, Niall Ó Murchadha, Istvan Racz, Alan Rendall, Andrzej Rostworowski, Bernd Schmidt, Walter Simon, Nikodem Szpak, Gabor Zsolt Toth, Juan Velazquez

Seminar on Mathematical Relativity

Organizers: R. Beig (Vienna), P. Bizoń (Krakow), P. Chrusciel (Vienna), H. Friedrich (Potsdam)

Dates: January 28 - 29, 2011

Budget: ESI € 2.678,–

Report on the programme

The seminar was attended by participants from Warsaw, Cracow, Prague, Budapest, Jena and Potsdam, as well as local participants from Vienna. The lectures were well attended, by further Viennese participants, as well as by participants from the Follow-up workshop to the 2010 ESI programme on "Quantitative Studies of Nonlinear Wave Phenomena" (P.C. Aichelburg, P. Bizoń), January 24 - 29.

The goal of the seminar was to initiate a yearly seminar at which graduate students from the above research centers can present their work, and where both graduate students and established researchers are exposed to research done at the other centers from the list (which is somewhat regional with the addition of Potsdam, which is one of the main centers for gravitational physics in the world). For this reason we had a charged programme of 20 short talks, allowing all graduate students who submitted an abstract to make a presentation.

The topics were spread across most areas of mathematical general relativity. Those by Jalmuzna (Krakow), Rostworowski (Krakow), Gaspar (Budapest) and Ansorg (Jena) were rooted in numerical studies. There were talks on gravitational energy by Kijowski (Warsaw) and his PhD student Drozd, as well as by Szabados (Budapest). Studies of axisymmetric solutions were discussed by Meinel (Jena), Ansorg (Jena) and Kofron (Prag). The talks by Szybka (Krakow), Eckstein (Krakow) as well as already mentioned Meinel (Jena) were concerned with black holes and their properties. Guerlebeck (Prag), Ansorg (Jena) and Simon (Krakow and Wien) discussed properties of fluids in general relativity. Higher dimensional problems arose in the talks by Aksteiner (Hannover), Szereszewski (Warszawa), as well as already mentioned Szybka and

Eckstein (both Krakow). A spectrum of other topics was covered by Grant (Wien; global properties of light cones), Avila (Golm; initial data); Scholtz (Prag; periodic solutions); Mach (Krakow; hydrodynamics)

The level of the talks was commensurate with the objective of the seminar. One talk was clearly outstanding, namely the presentation by Rostworowski (Cracow) of his numerical simulations with Bizoń, that suggest that perturbations of anti-de Sitter space-time, no matter how small, will lead to black hole formation; a rather unexpected result if confirmed.

The next seminar in this series is being planned in Cracow in February 2012.

Invited Scientists: Steffen Aksteiner, Marcus Ansorg, Gaston Avila, Robert Beig, Jiri Bicak, Pawel Biernat, Piotr Bizoń, Stephan Broda, Piotr Chrusciel, Roland Donninger, Nadbor Drozd, Michal Eckstein, Helmut Friedrich, Merse Elod Gaspar, Arne Goedeke, James Grant, Nishanth Abu Gudapati, Norman Gurlebeck, Joanna Jalmuzna, Jacek Jezierski, Jerzy Kijowski, David Kofron, Andras Lazlo, Tomas Ledvinka, Bernadette Lessel, Jerzy Lewandowski, Marek Lipert, Patryk Mach, Maciej Malibordki, Reinhardt Meinel, Pawel Nurowski, Tim-Torben Paetz, Istvan Racz, Alan Rendall, Andrzej Rostworowski, Bernd Schmidt, Martin Scholtz, Walter Simon, Laszlo Szabados, Adam Szereszewski, Nikodem Szpak, Sebastian Szybka, Juan Velazquez.

Non-commutative Geometry, Scattering Theory and Witten Index

Organizers: A. L. Carey (ANU), H. Grosse (Vienna), F. Gesztesy (Missouri), F. Sukochev (UNSW)

Dates: January 31 - February 4, 2011

Budget: ESI €3.624,–

Report on the programme

Over twenty years ago Bolle, Gesztesy, Grosse, Schweiger, and Simon showed that under certain conditions on the Hamiltonian of a supersymmetric quantum system, there is a regularized Witten index and it equals minus the jump in the Krein spectral shift function from quantum scattering theory. Later this was proved by some of the organizers and their collaborators to be precisely the spectral flow. There is also a remarkable parallel between other questions in the study of spectral flow and Witten index computations. Both involve relatively trace class perturbations.

Great progress in the interaction between index theory, spectral flow and the Krein spectral shift function using the new method of double operator integration was recently made, also in part by some of the organizers. This work is also sufficient to understand the Witten index in the Fredholm case. The issue unresolved at this time is the meaning of the supersymmetric quantum mechanical Witten index in the non-Fredholm case. It is real-valued and so not a Fredholm index in the usual sense. A focus of the workshop was a discussion of semifinite index theory which may provide an interpretation of the real-valued Witten index. An alternative possibility also touched on at the meeting is the connection with boundary value problems in index theory and the eta invariant.

Other recent advances in spectral flow and index theory were discussed by Sukochev, Tomilov and Pushnitski. Fedor Sukochev explained some results in spectral flow which show that the spectral flow does not depend on special choices of the function chosen to take unbounded Fredholm operators to bounded ones. He showed that an analogous result also holds in the spectral shift

function theory. The lecture by Yuri Tomilov centered around the infinite-dimensional dichotomy theorem in a Banach space X and its intimate relation with Fredholm properties of operators of the type $G = (d/dt) + A(\cdot)$ in $L^p(\mathbf{R}; X)$. Moreover, the Fredholm index of G is expressed in terms of appropriate dichotomy projections. The talk by Alexander Pushnitski focused on spectral theory of discontinuous, more precisely, piecewise continuous, functions of a pair of self-adjoint operators and a description of the scattering matrix and its eigenvalues and angles of associated eigenspaces corresponding to this pair. In addition, the index of a pair of spectral projections was discussed.

These lectures demonstrated the close interaction between the various topics of the workshop and this was further emphasised in the discussion sessions on Thursday and Friday where questions for further research were raised. In addition Matthias Lesch gave a short lecture on the work of M. Breuer who unfortunately died on January 31, 2011. Breuer began the study of semifinite index theory.

Invited Scientists: Asao Arai, Alan Carey, Victor Gayral, Fritz Gesztesy, Harald Grosse, Matthias Lesch, Alexander Pushnitski, Adam Rennie, Fedor Sukochev, Yuri Tomilov.

Topological Heterotic Strings and (0,2) Mirror Symmetry

Organizers: J. Distler (U.S.A.), J. Knapp (Tokio), M. Kreuzer† (Vienna), I. Melnikov (Germany)

Dates: June 20 - 24, 2010

Budget: ESI €3.685,– ; ESF €7.703,–

Preprints contributed: [2299]

Report on the programme

The last few years have seen a revival of interest in the mathematical structure of heterotic string theories and its physical implications. This study is being undertaken by both mathematicians and physicists, and the goal of the workshop was to bring together a number of experts in the field to review recent progress, discuss current problems, and formulate some new directions of research. The format was deliberately not too lecture-intensive, leaving plenty of time for discussions, meetings and ongoing collaborations.

The meeting largely succeeded in its goals. There were many lively discussions initiated in the seminars and then continued later in the day. These included "cross-cultural" exchanges between the mathematicians and physicists, for example as a follow-up to Donagi's and Sharpe's presentations of a mathematically rigorous formulation of quantum sheaf cohomology; as well as researchers tackling related questions that were encountered by different groups, as in the discussions of torsional linear sigma models between Adams, Groot Nibbelink, and Quigley and Sethi (shortly after the workshop Nibbelink and collaborators, as well as Quigley and Sethi published closely related works on the subject). As a result of the discussions at the event a number of new collaborations are pursuing new lines of research.

Scientific content of the talks

- Thorsten Rahn spoke about *Landscape study of target space duality of* $(0, 2)$ *heterotic string models*. He discussed a target space duality of $(0, 2)$ models which changes the Hodge numbers of the Calabi-Yau as well as the number of bundle moduli while keeping

their sum constant. The duality is based upon a linear sigma model construction, where in certain phases it is possible to re-interpret some of the two-dimensional fields associated to the base manifold as fields associated to the gauge bundle. Although not all steps in this re-interpretation are completely understood, the numerical evidence, obtained by a systematic computer search, suggests that this duality is a property of many compactifications based on linear sigma models.

- Roberto Zucchini spoke about *A heterotic sigma model with novel target geometry.* He discussed sigma models whose targetspaces are Lie algebroids over Kähler manifolds. A Lie algebroid is a vector bundle equipped with a Lie bracket and a natural map to the tangent bundle of the base manifold. These structures were reviewed in some depth in the talk. Such models serve as laboratories for topological heterotic strings as they have $(1,2)$ supersymmetry, making them potentially more tractable than their less symmetric $(0,2)$ relatives. It is possible to make two topological twists, leading to a pair of half-twisted models which have two BRST operators constructed from the $(0,2)$ and the $(1,0)$ components of the supersymmetries. The speaker furthermore commented on the chiral algebras and chiral rings in these sigma models — a subject related to the work of Meng-Chwan Tan reviewed below.

- Katrin Becker talked about *Disk amplitudes, picture changing and space-time actions.* She discussed higher derivative (fourth-order) corrections to D-brane actions. The existence of such corrections was motivated by using a T-duality argument, and an explicit calculation of such a correction in the linearized approximation was obtained by explicitly calculating a disk scattering amplitude with a RR-field, a B-field and gravitons.

- Melanie Becker gave a review on *Heterotic flux, where do we stand?* — an overview of the space-time approach to construction of heterotic compactifications with fluxes, focusing in particular on models with torsional (i.e. non-Calabi-Yau) geometries. A duality between models with Kähler geometry and non-Kähler models with torsion was outlined and discussed for the example of $K3 \times T^2$. The duality was explained via a common M-theory origin of the models. Further examples with $N = 0, 1, 2$ supersymmetry were discussed.

- Ilarion Melnikov's talk was titled *Tracking massless singlets in heterotic compactifications.* He addressed the issue of moduli in heterotic compactifications, focusing on the bundle moduli in the case where the gauge bundle is the tangent bundle. Due to classical obstructions which depend on the base manifold's complex structure, as well as quantum obstruction coming from worldsheet instantons, it is hard to determine the number of moduli. A subset of the bundle moduli is accounted for by $(0,2)$-deformations of the gauged linear sigma model. Several examples where the numbers of bundle moduli were counted at various points in moduli space were discussed.

- Jock McOrist spoke about *The $E_6 \to SO(10)$ Higgs mechanism in the linear sigma model*, focusing on the example of the quintic with gauge bundle $T_X \oplus \mathcal{O}$. He discussed issues that arise when one breaks the E_6 gauge group to $SO(10)$ by turning on VEVs linear sigma model operators that correspond to matter fields in spacetime. Although such a deformation exists in the underlying conformal field theory, it turns out to be a subtle matter to correctly implement it in the linear model: a naive form of the deformation leads to an inconsistent spectrum on the Landau-Ginzburg locus. Nevertheless, by using mirror symmetry it is shown how to correctly describe the deformation by taking into account maps in the Landau-Ginzburg BRST cohomology that violate the quantum symmetry of the orbifold. In the space-time picture this amounts to keeping track of the kinetic term normalizations.

- In his talk *Linear sigma models with torsion* Savdeep Sethi discussed how to define an extension of a gauged linear sigma model which leads to torsional geometries in the heterotic string. The construction turns on a two-dimensional realization of the Green-Schwarz mechanism: one considers a (0,2) supersymmetric linear sigma model with a holomorphic field-dependent Fayet-Iliopoulos coupling that fails to be gauge invariant; however, the non-invariance is chosen just right to cancel the one-loop gauge anomaly coming from the variation of the measure. By integrating out the gauge fields, one obtains an effective description of the light degrees of freedom as a non-linear sigma model. The resulting geometry is a complete intersection in a non-Kähler generalization of a toric variety. The construction gives a potentially large class of smooth compact torsional geometries with a linear sigma model realization. The latter feature should be useful in studying quantum aspects of heterotic compactifications with flux.

- Stefan Groot Nibbelink discussed *Anomaly cancellation in* $(0,2)$ *heterotic orbifold resolutions.* He explained how (resolutions of) non-compact heterotic orbifold models with VEVs for twisted states can be embedded into a gauged linear sigma model. It turns out that solving the anomaly cancellation conditions of the GLSM implies that the Bianchi identities are satisfied for all resolutions of the orbifold singularity. In case one cannot find solutions to the anomaly cancellation conditions, one can implement a heterotic Green-Schwarz anomaly cancellation mechanism by introducing field-dependent FI-terms. Singularities of these FI-terms can be interpreted as NS5-branes in the target space.

- Eric Sharpe and Ron Donagi gave a joint session on *Quantum Sheaf Cohomology*, which is the $(0,2)$ generalization of the quantum cohomology of the topological A-model. Eric Sharpe gave a general introduction to the subject and discussed the type A half-twist of a $(0,2)$ theory based on a non-linear sigma model for a Calabi-Yau manifold equipped with a holomorphic gauge bundle satisfying the Green-Schwarz anomaly cancellation conditions. His talk focused on the classical spectrum and correlation functions. In order to define the quantum corrections due to world-sheet instantons, one must define the pull-back of the gauge bundle to the moduli space of maps from the worldsheet to the target. The resulting structure is in general a sheaf with certain regularity properties.
  In the second part of the talk Ron Donagi explained how to compute the quantum sheaf cohomology relations in the case where the targetspace is a compact smooth toric variety and the bundle is a deformation of the tangent bundle. These algebraic relations can be obtained as certain ideals in the space of polynomials with indeterminates corresponding to a basis of the Picard lattice of the toric variety. The computations are carried out by relating different instanton contributions to the correlators. The correlation functions in a particular instanton sector are encoded in the symmetric product of the Picard group of the associated toric space modulo an ideal determined by the primitive collection. Using techniques of toric geometry and Koszul resolution, the quantum sheaf cohomology relations can be computed explicitly, as illustrated in the example of $\mathbb{P}^1 \times \mathbb{P}^1$. It was pointed out that the results in different instanton sectors are compatible and that there is agreement with results obtained earlier by physics methods.

- Meng-Chwan Tan gave a review entitled *A quasi-topological* $(0,2)$ *heterotic B-model, the mirror chiral de Rham complex, and twisted generalized mirror symmetry.* He discussed a B-twisted $(0,2)$ sigma model and its perturbation theory. After imposing anomaly cancellation conditions, one gets an infinite tower of states with holomorphic weights. The observables in the theory form a holomorphic chiral algebra whose ground states span a finite-dimensional chiral ring. This is the (0,2) analogue of the more familiar (a,c) and (c,c) rings of $(2,2)$ theories.
  For non-zero torsion the observables are described in terms of certain Čech cohomology

groups. In the general case this structure in encoded in the theory of chiral differential operators, which reduces to the chiral de Rham complex at the $(2,2)$-locus. Locally this can be described in terms of a $bc-\beta\gamma$-system. Obstructions to gluing local patches corresponds to the conformal anomaly in the sigma model, i.e. a non-trivial β function.

- Jacques Distler talked about *Quantized Fayet-Iliopoulos terms in $N = 1$ supergravity.* The talk began with a review of the constraints that a $D = 4$ $N = 1$ supersymmetric non-linear sigma model must satisfy in order to be consistently coupled to either gauge fields or supergravity. The former requires the existence of holomorphic isometries that can be represented by Hamiltonian vector fields; the latter requires the scalar manifold to be a Kähler-Hodge manifold. It was shown that putting these two requirements together leads to a quantization condition on the F-I terms — the integration constants appearing in the moment maps associated to $U(1)$ isometries. The procedure was illustrated by a $\mathbb{CP}^1$-example.

- Allan Adams discussed the *Landau-Ginzburg phases of linear sigma models with torsion.* It was shown that the Landau-Ginzburg phase of a torsional gauged linear sigma model is described by an orbifold with additional phase factors (not related to standard discrete torsion constructions), i.e. one where contributions of various twisted sectors to the partition function acquire non-trivial phase factors. These factors are the small-radius avatars of the non-trivial anomaly cancellation visible in the geometric phase.

- Anda Degeratu spoke about *Invariants of elliptically fibered Calabi-Yau threefolds.* She talked about heterotic/F-theory duality for heterotic stings on K3 vs. F-theory on elliptically fibered Calabi-Yau threefolds. It was shown that the charged massless hypermultiplet spectrum matched in the conjectured dual theories. In the heterotic string this number arises from an index related to the moduli spaces of antiselfdual representations of the gauge bundle whereas in F-theory the result is encoded in the singularity structure of the elliptic fibration. This provides another important check of the duality conjecture between six-dimensional type II and heterotic compactifications.

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

The workshop highlighted a number of new developments in the field, and both during the presentations themselves, as well as subsequent discussions, many new questions were posed. In this remaining section of the review, we will discuss a few of these future directions and the impact they might have on the field, as well as related larger areas of mathematics and string theory.

As was saw in a number of talks, we have by now a fairly good understanding of the ground ring in (0,2) theories that are obtained as deformations of (2,2) supersymmetric models. This leads to two obvious questions: can we generalize the known techniques to more general (0,2) theories? can we connect this work with the efforts, as reviewed by Tan, to understand the full infinite dimensional chiral ring? A quantitative understanding of the first issue would lead to methods to compute superpotential couplings in phenomenologically interesting heterotic models, as well as enable us to test generalizations of the mirror conjecture in the (0,2) setting. The second issue, while certainly more challenging, is also important: it would lead to a new sort of string theory – a half-way point between the familiar topological string and the physical string.

Another exciting set of developments presented at the workshop was a general construction of torsional gauged linear sigma models. Building on previous work of Adams et. al., S. Groot Nibbelink and collaborators, as well as Quigley and Sethi developed a more general framework

for studying torsional geometries that should correspond to conformal (0,2) theories. The work of the former described non-compact models with NS5-brane sources; the latter work aims to build compact models by generalizing the familiar toric quotient to manifolds with torsion. These developments offer a potential to produce many new interesting geometries that can be used to test ideas about chiral rings and mirror symmetry, as well as to build interesting phenomenological models of the heterotic string.

The talks of Melnikov, McOrist, and Rahn produced some interesting questions regarding deformations of (0,2) theories. A common theme was the surprising existence of deformations, whether exact or even just first-order in many (0,2) theories. Understanding this deformation space and how obstructions can arise will certainly be an important direction to pursue in the future. It would be very interesting to study singularities that arise in these moduli spaces, especially since the existence of such features has important consequences for the global structure of the moduli space. It may well be that various quantization conditions, such as those described by Distler, may be modified once these singularities are taken into account.

As a final topic of future interest, we might mention the construction of non-supersymmetric vacua. As described by M. Becker and also mentioned by A. Adams, there are certain natural extensions of the known torsional constructions that yield $N = 0$ supersymmetry in spacetime. Are these models still stable, i.e. do they correspond to conformal field theories? This, and related constructions, were discussed at some length during the workshop, and it is likely that this question will be pursued in future investigations.

A future workshop related to these investigations is already scheduled to take place at BIRS in Banff, Canada in December of 2012.

Invited Scientists: Allan Adams, Katrin Becker, Melanie Becker, Ralph Blumenhagen, Philip Candelas, Huai-Liang Chang, Anda Degeratu, Xenia De la Ossa, Jacques Distler, Ron Donagi, Stefan Groot Nibbelink, Benjamin Jurke, Johanna Knapp, Jock McOrist, Ilarion Melnikov, Ruben Minasian, Callum Quigley, Thorsten Rahn, Eric Sharpe, Emanuel Scheidegger, Savdeep Sethi, Meng-Chwan Tan, Bernhard Wurm, Roberto Zucchini.

Memorial Conference for Maximilian Kreuzer

Organizers: L. Katzarkov (Vienna), J. Knapp (Tokio), A. Rebhan (Vienna), E. Scheidegger (Augsburg)

Dates: June 25 - 28, 2010

Report on the programme

The aim of the conference was to honor the scientific achievements of Prof. Maximilian Kreuzer who had passed away on November 26, 2010. The participants were former collaborators and students of Maximilian Kreuzer.
There were 57 registered participants, among them prominent physicists and mathematicians such as Philip Candelas, Michael Douglas, Peter van Nieuwenhuizen, Ron Donagi and Dimitri Orlov. The programme consisted of 24 50-minute talks, 6 30-minute talks, one discussion session, and furthermore a conference dinner.
Additional funding for the conference was provided by the European Research Council, the Vienna University of Technology, the Department of Mathematics of the Kansas State University, the Algebraic Geometry group of the University of Vienna and the Laboratory of Algebraic Geometry and its applications in Moscow.
The proceedings of this conference will be published by World Scientific as a memorial volume

for Maximilian Kreuzer with the title "Strings, Gauge Fields and the Geometry Behind – The Legacy of Maximilian Kreuzer".

The scientific programme of the conference was very diverse, reflecting the broad range of Maximilian Kreuzer's interests. Therefore the conference provided the opportunity for interactions between researchers of various fields in mathematics and physics. There were three main topics:

1. String Theory, Calabi-Yau Manifolds and Algebraic Geometry
2. Gauge Theories, Supergravity and Conformal Field Theory
3. Derived Categories and Homological Mirror Symmetry

The first part focused on Maximilian Kreuzer's contributions to string theory. In particular the classification of Calabi-Yau threefolds he achieved together with Harald Skarke and its impact in string theory and algebraic geometry was highlighted in many talks. The following speakers have contributed talks: Victor Batyrev, Ralph Blumenhagen, Volker Braun, Philip Candelas, Ron Donagi, Michael Douglas, Sebastian Guttenberg, Manfred Herbst, Stefan Hohenegger, Albrecht Klemm, Christoph Mayrhofer, Benjamin Nill, Rolf Schimmrigk, Harald Skarke and Nils-Ole Walliser.
The second part focused on Maximilian Kreuzer's scientific contributions to gauge theories, supergravity and conformal field theory. Talks on these subjects were given by Friedemann Brandt, Norbert Dragon, Jürgen Fuchs, Harald Grosse, Cristoph Schweigert and Peter van Nieuwenhuizen.
The third part focused on the mathematical work of Maximilian Kreuzer. Speakers were Fedor Bogomolov, Alexander Efimov, David Favero, Herwig Hauser, Paul Horja, Dimitri Orlov, Helge Ruddat and Alexander Polishchuk.

Invited Scientists: Rashid Ahmad, Matthew Ballard, Victor Batyrev, Katrin Becker, Ralph Blumenhagen, Fedor Bogomolov, Friedemann Brandt, Andreas Braun, Volker Braun, Philip Candelas, Ching-Ming Chen, Rhys Davies, Ron Donagi, Charles Doran, Michael R. Douglas, Norbert Dragon, Alexander Efimov, David Favero, Sergey Galkin, Vasily Golyshev, Thomas Grimm, Harald Grosse, Sebastian Guttenberg, Herwig Hauser, Manfred Herbst, Stefan Hohenegger, R. Paul Horja, Alexander M. Kasprzyk, Ludmil Katzarkov, Albrecht Klemm, Johanna Knapp, Andre Lukas, Christoph Mayrhofer, Ilarion Melnikov, Benjamin Nill, Dmitri Orlov, Alexander Polishchuk, Victor Przyjalkowski, Andrea Puhm, Radoslav Rashkov, Anton Rebhan, Helge Ruddat, Emanuel Scheidegger, Bert Schellekens, Rolf Schimmrigk, Maria Schimpf, Karl-Georg Schlesinger, Christoph Schweigert, Savdeep Sethi, Eric Sharpe, Dmytro Shklyarov, Harald Skarke, Peter van Nieuwenhuizen, Misha Verbitsky, Nils-Ole Walliser, Robert Wimmer, Ilia Zharkov.

ESF-EMS-ERCOM Conference "Completely Integrable Systems and Applications"

Organizers: Gerald Teschl (Vienna), Spyros Kamvissis (Crete)

Budget: ESI €8.756,– ; ESF €18.543,– ; BMWF €6.000,–

Dates: July 3 - 8, 2011

Report on the program

The conference was focused on a few very active areas in the theory of integrable systems, including PDEs, ODEs and discrete (in space and time) systems.

- One such was the area of initial boundary value problems for integrable equations and the application and rigorous justification of the generalized inverse scattering method initiated by Fokas and his collaborators. (Talks by Bona, Boutet de Monvel, Chen, Fokas, Hitzazis Lennels, Mantzavinos, Pelloni).

- A second focus was the further development of the asymptotic method of Deift and Zhou which relies on the Riemann-Hilbert formulation of initial and initial boundary value problems for integrable systems. (Talks by Baik, Cafasso, Do, Grava, Kamvissis, Kuijlaars, Mikikits-Leitner, Miller. Moro, Shepelsky).

- A third focus was on random matrices and related problems arising in probability. (Talks by Baik, Kuijlaars, Soshnikov, van Moerbeke, Wang). The talk of Kuijlaars was a very interesting tying up of recent work on orthogonal and biorthogonal polynomials, nonintersecting Brownian motions, random matrix models and the Hele-Shaw problem, Riemann-Hilbert problems and equilibrium measures for logarithmic potentials.

- Also a very interesting development was presented by Srinivasan concerning the appearance of integrable models in the study of Burgers turbulence.

- Other points of focus included the work of the Trieste school on the study of non-integrable Hamiltonian PDEs before and during break via integrable techniques (Grava, Masoero, Moro, Wu), peakons and the Camassa-Holm and Degasperis-Procesi equations (Constantin, Eckhart, Gesztesy, Grunert, Lundmark, Szmigielski), some recent results on the Ablowitz-Ladik lattice (Michor, Nenciu) and Weyl functions (Rybkin, Sakhnovich) as well as connections with theta functions and algebraic geometry (Kalla, Kamvissis, Konopelchenko) and state of the art numerical work (Kalla).
  We should also mention the presentation of work by the Kharkiv team and collaborators on step-like initial value problems (Egorova, Minakov), the presentation of recent work on semiclassical limits (Masoero, Miller, Sergyeyev) and the singular presentations of Holden on the nonlinear variational wave equation and Quispel of recent results in discrete (in space and time) integrable systems.

In the first session we had a general presentation of the inverse scattering method for boundary initial value problems for integrable equations of Fokas and a presentation of some applications of the method to the Ernst equation by Lenells.

The second session included a presentation by Bona of different aspects of nonlinear dispersive, not necessarily integrable equations, including questions of well-posedness and stability. It was followed by a talk of Pelloni on the application of the Fokas method to the elliptic Sine-Gordon equation.

The third session started with Konopelchenko who discussed local properties of the families W of algebraic varieties in Birkhoff strata of the Sato Grassmanian containing hyperelliptic curves. This was followed by Cafasso who showed how one can approximate a Pearcey process by Airy processes using a suitable variable rescaling. Hongqiu Chen spoke about long wave limits of periodic solutions of nonlinear wave equations in Sobolev spaces. Finally, Yen Do presented his work on how to extend the Deift-Zhou method for Riemann-Hilbert problems with non-analytic phase, based on earlier work of Varzugin.

The fourth session started with Grunert who presented work with Holden and Raynaud on a Lipschitz metric enabling them to study the stability of some conservative solutions to the Camassa-Holm equation. Nenciu talked about work with L.-C. Li on the Liouville integrability of the Ablowitz-Ladik by use of an appropriate Poisson-Lie group. Hitzazis presented his work

on the application of the Fokas method on KdV in an interval and also some higher dimensional equations. Eckhart presented work with Teschl on the spectral theory for Sturm-Liouville problems appearing in the dispersionless Cmassa-Holm equation. Sergyeyev presented work with Marvan on a general method for constructing recursion operators for multidimensional integrable dispersionless systems.

In the fifth session Holden presented a proof of existence of a global semigroup of conservative solutions of the nonlinear variational wave equation. Constantin described how the Camassa-Holm end Degasperis-Procesi equations arise in the modeling of the propagation of shallow water waves over a flat bed.

In the sixth session Grava gave a progress report of the Trieste school on the Dubrovin conjecture concerning behaviour of solutions of Hamiltonian PDEs near critical points and their relation to solutions of Painleve equations. Baik presented recent work on maximal crossings and nestings of random complete matchings and their asymptotic analysis via Riemann-Hilbert methods.

In the seventh session Rybkin made a link of the theory of Hankel operators to completely integrable systems and as a consequence yielded new well-posedness results for KdV. Peter Miller talked on recent results about the semiclassical Sine-Gordon equation. Minakov analysed a shock problem for mKdV with step-like initial data via Riemann-Hilbert techniques. Moro showed how the balance equation for a gas in thermodynamic equilibrium is equivalent to an integrable nonlinear system of equations of hydrodynamic type and discussed the critical point of gradient catastrophe.

In the eighth session, Soshnikov discussed results about the fluctuation of the outliers in the spectrum of finite rank deformations of Wigner random matrices and results about the fluctuation of the matrix entries of regular functions of Wigner and sample covariance random matrices. Sakhnovich presented several examples and new results on the Weyl theory and inverse spectral transform for the Dirac system with rectangular potential. J. Michor showed that for decaying solutions of the Ablowitz-Ladik system the leading asymptotics are time independent and that bounded solutions that are asymptotically close at time zero remain so forever. Szmigielski presented a construction of peakon solutions to an integrable system first introduced by Geng and Xue. His construction uses Hermite-Pade approximants and Cauchy biorthogonal polynomials. Kavitha Louis talked about the integrability and the magnetization dynamics of ferro- and antiferromagnets.

In the ninth session the talk of Anne Boutet de Monvel presented work with Kotlyarov and Shepelsky concerning long time asymptotics of the focusing NLS equation with steplike data via Riemann-Hilbert techniques. Shepelsky's talk presented long time asymptotics for the short-wave model for the Camassa-Holm equation, also via Riemann-Hilbert techniques.

In the tenth session Kuijlaars talked about the normal matrix model and accumulation of eigenvalues in two-dimensional regions in the complex plane when the dimension of the matrices is large. He presented a way to redefine orthogonality in terms of a well-defined Hermitian form and formulated a Riemann-Hilbert problem for the resulting multi-orthogonal polynomials. He presented an asymptotic analysis (work with P. Bleher) in the case of a cubic potential. Srinivasan presented work with G. Menon on a stochastic coalescence model arising when considering shock statistics in scalar conservation laws with Markov initial data. The evolution is a completely integrable equation, analogue of the N-wave model in nonlinear optics.

In the eleventh session Egorova presented a rigorous inverse scattering theory for steplike problems for KdV and Toda, and also some long time asymptotics. Kamvissis presented work with Teschl on long time asymptotics for a perturbed periodic Toda lattice, using the nonlinear stationary phase analysis of a Riemann-Hilbert posed on a Riemann surface.

In the twelfth session van Moerbeke presented work on the tacnode process, which appears when non-intersecting random walks or Brownian motions meet momentarily. Gesztesy presented work with Weikard on a generalization of the spectral problem underlying the Camassa-Holm hierarchy using a Birman-Schwinger type operator approach.

In the thirteenth session, Dong Wang discussed worked with Baik on the limiting distribution of the top eigenvalues of Hermitian matrices with general potential when the external source is of finite rank (spiked). Quispel presented recent results on discrete integrable systems. Chaozhong Wu presented a quasi-triviality result for all orders, in the spirit of Dubrovin's work on Hamiltonian perturbations of evolutionary PDEs. Enolskii's talk was about SU(2) monopoles of charge 3 in the Bogomolny-Prasad-Sommerfeld limit.

In the fourteenth session, Mantzavinos talked about applications of the Fokas methods to 2+1 dimensional integrable models. Masoero presented a result with Raimondo on the convergence of solutions of the small dispersion KdV to solutions of the Burgers equation, before the break. Lundmark talked about constructing n-peakon solutions of Camassa-Holm and Degasperis-Procesi via orthogonal and biorthogonal polynomials. Mikikits-Leitner presented work with Teschl on the long time behavior of the perturbed finite gap KdV, using the Riemann-Hilbert method on Riemann surfaces initiated by Kamvissis and Teschl. Kalla presented a theoretic and numerical work with C. Klein on the multicomponent NLS system.

Overall the results presented were of a very high caliber, at the heart of mainstream research, and we expect them to be of seminal importance in the development of the field of integrable systems.

Further information can be found on the conference website: `http://www.esf.org/activities/esf-conferences/details/2011/confdetail369.html`

Invited Scientists: Simonetta Abenda, Jinho Baik, Mariusz Bialecki, Jerry Bona, Anne Boutet de Monvel, Mattia Caffaso, Alan Carey, Adrian Constantin, Hongqiu Chen, Yen Do, Iryna Egorova, Victor Enolskii, Fritz Gesztesy, Riccardo Giachetti, Tamara Grava, Inna Basak Gancheva, Katrin Grunert, Davide Guzzetti, Iason Hitzatzis Umid Hoitmetov, Helge Holden, Caroline Kalla, Spyros Kamvissis, Marcus Kardell, Boris Konopeltchenko, Arno Kuijlaars, Jonatan Lenells, Hans Lundmark, Dionyssios Mantzavinos, Davide Masoero, Johanna Michor, Alicee Mikikits-Leitner, Peter David Miller, Oleksandr Minakov, Antonio Moro, Irian Nenciu, Beatrice Pelloni, Reinout Quispel, Alexei Rybkin, Alexander Sakhnovich, Artur Sergeyev, Dmitry Shepelsky, Alexander Soshnikov, Ravi Srinivasan, Jacek Szmigielski, Gerald Teschl, Pierre van Moerbeke, Dong Wang, Jiuguang Wang, Sergey Zyklov.

Cartan Connections, Geometry of Homogeneous Spaces, and Dynamics

Organizers: A. Cap (Vienna), C. Frances (Université Paris Sud), K. Melnick (University of Maryland)

Dates: July 10 - 23, 2011

Budget: ESI €21.440,–

Preprints contributed: [2308], [2309], [2333], [2343], [2344], [2348], [2353[, [2355], [2357]

Report on the programme

This was a two week workshop in the field of differential geometry. The titles for the two weeks were "Conformal geometry and generalizations", and "Geometry of homogeneous spaces and dynamics", respectively. The workshop took place during the thematic programme "Dynamics

of General Relativity: Numerical and Analytical Approaches", and there was quite a lot of interaction between participants of the two activities, since topics in pseudo–Riemannian geometry were in the scope of both weeks of our workshop.

The first week was mainly devoted to parabolic geometries, a class of seemingly very diverse differential geometric structures, which can be studied in a surprisingly uniform and conceptual way via an equivalent description by a Cartan geometry. In addition, the homogeneous model of this Cartan geometry is the quotient of a semisimple Lie algebra by a parabolic subalgebra, which makes strong tools from representation theory applicable. Conformal geometry is one of the simplest and best studied instances of a parabolic geometry and serves as a model case for more general structures.

The central topic for week two was group actions preserving geometric structures, automorphism groups of geometric structures (in particular rigid geometric structures in the sense of Gromov) and geometry of homogeneous spaces. In this context, methods of topology, measure theory and dynamics play an important role.

The topics of both weeks can be considered as well established and there are rather large communities working in both directions. Traditionally, there was only little exchange between the two communities. These exchanges have increased recently, partly due to activities of the organizers of the workshop. In particular, it has turned out that Cartan geometries can serve as a nice setting to study the group theoretic restrictions coming from actions preserving geometric structures. Indeed, several of the fundamental theorems have been reproved, often in strengthened versions, for Cartan geometries. Trying to expose people working in one of the two fields to the other and getting more interaction between the two communities started was one of the main motivations for organizing this workshop. Another important aim was to include young people and the large number of junior participants and the resulting lively atmosphere was a very nice feature of the workshop. It should be pointed out that in addition of the support from the ESI, the activity obtained additional support by the NSF and by several participants attending on their own funds.

The workshop had a fairly extensive programme of lectures by the participants, with a total of 25 lectures in the first week and 21 lectures in the second. The detailed schedules for the two weeks are accessible via the web page of the conference `http://www.mat.univie.ac.at/$\sim$cap/files/esiprog11.html`. To support the interaction between the two communities, we organized several expository and introductory talks. Moreover, in each of the two weeks one afternoon was reserved for five shorter talks by junior participants.

We should mention one more important outcome of the programme. Two of the organizers (A.C. and K.M.) were asked to serve as guest editors for a special issue of the Central European Journal of Mathematics related to our workshop and the conference "Finite Dimensional Integrable Systems in Geometry and Physics" which took place in Jena in July 2011. This special issue will not have the character of proceedings but will be a regular issue of the journal following the usual standards of refereeing. Participants of the two activities were invited to contribute to this special issue. The contributions to this special issue are currently being refereed, it looks like this will be a very nice collection of articles.

Let us briefly describe the main topics of the talks in the two weeks. A significant feature for the first week was the interplay between conformal structures and more general geometric structures. For example, A. Derdzinski presented a detailed study of the zero sets of conformal Killing vector fields (which are solutions to a first BGG operator), while A.R. Gover discussed a general result relating the zero sets of solutions to arbitrary first BGG equations on projective structures to zero sets of solutions on the homogeneous model and thus to algebraic geometry.

Likewise, the detailed description of singularities of conformal mappings by C. Frances had B. Mc Kay's presentation of a general version of Hartogs theorem for arbitrary holomorphic parabolic geometries as a counterpart, and the talks by J. Alt and C.R. Graham on conformal holonomy were complemented by M. Hammerl's talk dealing with holonomy reductions of general Cartan geometries.

Within conformal geometry, a central topic were Einstein metrics and their conformal infinities as well as generalizations of the Einstein condition. The canonical Cartan connection, also in its equivalent presentation as tractor calculus, and the Fefferman–Graham ambient metric construction were the central technical tool in many talks.

In the realm of more general geometric structures, relations to the geometric theory of differential equations frequently played an important role. This concerned both the description of differential equations in terms of geometric structures and canonical structures on spaces of solutions to certain differential equations.

The second week had many participants with expertise on Lie groups and differential geometry, but who had not previously worked with Cartan connections. To introduce them to this useful tool, we had several introductory lectures in the second week: A. Čap on an introduction to Cartan geometries, J. Slovák on distinguished curves in Cartan geometries, and A.R. Gover on conformal tractors and infinitesimal automorphisms. K. Melnick gave a survey talk aimed to foster the exchange of ideas in the other direction, on the Gromov-Zimmer theory of rigid geometric structures and the formulation of this theory in the setting of Cartan geometries. This topic was echoed in Dumitrescu's presentation of locally homogeneous rigid geometric structures, motivated by Gromov's open-dense orbit theorem.

A first corpus of research talks in the second week dealt with automorphisms of rigid geometric structures, and actions of "large groups" preserving such structures. In the spirit of the so called Zimmer's program, Zeghib presented results classifying actions of big lattices on compact Kähler manifolds. Other geometric structures admitting a big automorphism groups were also considered: projective structures (V. Matveev and G. Manno), Lorentz metrics having a transitive action of a semi-simple group (D. Alekseevski), rank one parabolic geometries (C. Frances). K. Neusser presented results toward the understanding of the automorphism group of certain generic plane distributions.

Locally homogeneous spaces, or in other words locally flat Cartan geometries, was another important theme that appeared in many talks. Specific homogeneous models included anti-de Sitter manifolds (F. Kassel), real projective manifolds (L. Marquis), conformally flat Lorentz manifolds (Y. Kamishima and C. Rossi), and Margulis space-times (D. Ruiz). D. Constantine proved a restriction on existence of compact Clifford-Klein forms for rather general homogeneous spaces of simple groups. I. Kath presented us her results about symmetric spaces admitting parallel $G_{2(2)}$-structures, and their classification.

Other talks dealing with more transversal topics, sometimes related to physics, were proposed during the week, including those of R. Feres, K. Mann and J.P. Michel.

Throughout the meeting, the lectures were very well attended and usually led to lively discussions. In view of the form of the workshop it is clear that one cannot expect immediate scientific output in form of preprints initiated during the workshop. The main role here is to start collaborations and interactions. We had the clear impression that the workshop served this purpose very well. This not only concerns interactions within the topic of one of the two weeks. The meeting has also was a first step towards a more intensive exchange ideas between the two communities, which can be expected to be very fruitful in the future.

Invited Scientists: Dmitri Alekseevski, Jesse Alt, Thierry Barbot, Helga Baum, Olivier Biquard, Andreas Cap, Jeffrey Case, Stephen Casey, David Constantine, Yves Cornulier, Andrzej Derdzinski, Boris Doubrov, Quentin Dufour, Sorin Dumitrescu, Maciej Dunajski, Michael Eastwood, Renato Feres, Matthias Fischmann, Charles Frances, Francois Gueritaud, Jan Gregorovic, A. Rod Gover, Robin Graham, Matthias Hammerl, Kengo Hirachi, Jun-Muk Hwang, Andreas Juhl, Pierre Julg, Yoshinobu Kamishima, Fanny Kassel, Ines Kath, Wojciech Krynski, Svatopluk Krysl, Brad Lackey, Thomas Leistner, Felipe Leitner, Christian Luebbe, Kathryn Mann, Gianni Manno, Michael J. Markowitz, Ludovic Marquis, James Mathews, Vladimir Matveev, Ben McKay, Karin Melnick, Thomas Mettler, Jean-Philippe Michel, Daniel Monclair, Joel Merker, Katharina Neusser, Pawel Nurowski, Bent Orsted, Samuel Pocchiola, Stefan Roseman, Clara Rossi Salvemini, Masoud Sabzevari, Katja Sagerschnig, Tomas Salac, Daniel Schliebner, Domingo Ruiz, Josef Silhan, Jan Slovak, Petr Somberg, Vladimir Soucek, Arman Taghavi-Chabert, Dennis The, Barbara Tumpach, Vit Tucek, Zuzana Vlasakova, Ben Warhurst, Vojtech Zadnik, Lenka Zalabova, Abdelghani Zeghib., Igor Zelenko, Robert Ziimmer.

Summer School in Mathematical Physics

Organizers: C. Hainzl (Tübingen), R. Seiringer (McGill, Montreal)

Dates: August 16 - 24, 2011

Budget: ESI €23.430,–

Report on the programme

The summer school "Current Topics in Mathematical Physics" took place at the ESI in the period of August 16–24 2011. The school consisted of seven lecture series delivered by prominent and experienced scientists. Among the topics covered were Schrödinger operators, semiclassics and magnetic fields, phase transitions in statistical mechanics, the quantum many-body problems, and nonlinear partial differential equations. All these topics are currently under intense investigation, and hence the summer school presented a great opportunity for the participants to learn about relevant techniques and latest developments.

In the following we give a brief description of the content of the lecture series:

- **Rafael Benguria (PUC, Santiago, Chile): Isoperimetric inequalities for eigenvalues of the Laplace and Schrödinger operator.** Isoperimetric inequalities have a long history in mathematics dating back to the Greeks and Dido's problem, i.e., the classical isoperimetric inequality in Euclidean geometry. With the introduction of the Calculus of Variations in the seventeenth century, isoperimetric inequalities found their way into mechanics and physics. In 1856, Adhémar Jean Claude Barré de Saint Venant introduced the problem of determining the shape of the column of a given section having the maximal torsional rigidity, a problem that has important practical implications. Other physical quantities have been the subject of interesting isoperimetric inequalities as well, among them the electrostatic capacity. The theme of these lectures, isoperimetric inequalities for eigenvalues of the Laplacian, has its roots in the work of Lord Rayleigh on the theory of sound. It was determined in the nineteenth century that the basic equation that describes the small vibrations of an elastic medium is the wave equation. The normal modes and proper frequencies that characterize the vibrations of a fixed, homogeneous membrane correspond to particular solutions of the wave equation. They are determined by the solution of the eigenvalue problem for the Dirichlet Laplacian on a bounded domain in $\mathbb{R}^2$. Benguria's lectures gave an overview of some isoperimetric inequalities for eigenvalues of the Laplacian. Since the literature on the subject is extensive, the lectures were restricted

primarily to the consideration of isoperimetric results for low-lying eigenvalues with special attention to those connected to eigenvalue ratios.

- **Søren Fournais (University of Aarhus, Denmark): Semiclassics with self-generated fields.** These lectures were devoted to the Scott correction for large atoms and molecules in a self-generated magnetic field. A large neutral molecule in non-relativistic quantum mechanics was considered, with total nuclear charge Z and with a self-generated classical electromagnetic field. To ensure stability, it was assumed that $Z\alpha^2 \leq \kappa_0$ for a sufficiently small κ_0, where α denotes the fine structure constant. It was shown that, in the simultaneous limit $Z \to \infty$, $\alpha \to 0$ such that $\kappa = Z\alpha^2$ is fixed, the ground state energy of the system is given by a two term expansion $c_1 Z^{7/3} + c_2(\kappa) Z^2 + o(Z^2)$. The leading term is given by the non-magnetic Thomas-Fermi theory. The result shows that the magnetic field affects only the second (so-called Scott) term in the expansion.

- **Jürg Fröhlich (ETH, Zürich, Switzerland): States of matter and phase transitions accompanied by continuous symmetry breaking.** A short introduction to the subject of phase transitions and (continuous) symmetry breaking was presented. The Goldstone Theorem was proven. Some details of the method of reflection positivity and infrared bounds were exhibited. Applications to quantum field theory and statistical mechanics were outlined. The existence of phase transitions accompanied by continuous symmetry breaking and the appearance of Goldstone modes was established in some scalar quantum field models in three space-time dimensions, in classical Heisenberg and related lattice nonlinear σ-models, and in quantum XY models and Heisenberg anti-ferromagnets. Moreover, the Mermin-Wagner theorem and the McBryan-Spencer bounds were discussed. Comments were given on why the method fails for the ferromagnet and generic Bose gases.

- **Mathieu Lewin (Cergy-Pontoise, Paris, France): Geometric methods for nonlinear many-body quantum systems.** Geometric techniques have played an important role in the seventies, for the study of the spectrum of many-body Schrödinger operators. In these lectures a formalism was introduced which also allows to study nonlinear systems. A weak topology on many-body states was defined, which appropriately describes the physical behavior of the system in the case of lack of compactness, i.e., when some particles are lost at infinity. Several important properties of this topology were explained and used to write a simple proof of the famous HVZ theorem in the repulsive case. The method of geometric localization in Fock space as proposed by Derezinski and Gerard was recalled, and related to the weak topology. Several applications were discussed. Among those were finite-rank approximation which consists in imposing that the many-body wavefunction can be expanded using finitely many one-body functions. Another were translation-invariant many-body systems comprising a nonlinear term, which effectively describes the interactions with a second system. As an example, the existence of the multi-polaron in the Pekar–Tomasevich approximation was proved, for certain values of the coupling constant.

- **Vieri Mastropietro (Universita di Roma, Italy): Universality and critical behavior in Luttinger and Dirac liquids.** In these lectures, a proof was presented of the universality conjecture for a large class of weakly perturbed planar coupled Ising models or quantum spin chains. Such a conjecture states that the critical indices and some of the thermodynamic quantities, though model-dependent, verify a set of general universal relations. The validity of the conjecture can be checked in certain special integrable cases but its validity in non solvable models was up to now unproven. The analysis is based on the representation in terms of Grassmann integrals of the spin observables, combined with the Renormalization Group methods developed in Constructive Quantum Field Theory. The universal relations follow from the hidden local gauge invariance and the validity

of the Adler-Bardeen property of non-renormalization of the quantum anomalies in the asymptotic Ward Identities. Gauge invariance is exact only in the scaling limit, but the lattice corrections can be rigorously taken into account.

- **Fabio Toninelli (ENS Lyon, France): Zero-temperature dynamics of the three-dimensional Ising model and dimer covering fluctuations.** These lectures considered the Glauber dynamics for the Ising model with "+" boundary conditions, at zero temperature or at a temperature that goes to zero with the system size. In dimension $d = 3$ it was proved that an initial domain of linear size L of "–" spins disappears within a time T_+, which is at most $L^2(\log L)^c$ and at least $L^2/(c \log L)$ for some $c > 0$. The proof of the upper bound proceeds via comparison with an auxiliary dynamics which mimics the motion by mean curvature that is expected to describe, on large time scales, the evolution of the interface between "+" and "–" domains. The analysis of the auxiliary dynamics requires recent results on the fluctuations of the height function associated to dimer coverings of the infinite honeycomb lattice. The result, apart from the spurious logarithmic factors, is the first rigorous confirmation of the Lifshitz law $T_+ \approx \text{const} \times L^2$, conjectured on heuristic grounds. In dimension $d = 2$, T_+ can be shown to be of order L^2 without logarithmic corrections; the lower bound was described in the lectures. For $d = 2$, it was also shown that the spectral gap of the generator behaves like c/L for L large, as previously conjectured.

- **Wilhelm Schlag (University of Chicago, USA): Invariant manifolds and dispersive Hamiltonian Equations.** These lectures demonstrated how the notion of an invariant (stable, unstable, center) manifold arises naturally in the study of long-term dynamics of solutions to unstable dispersive Hamiltonian evolution equations, such as semilinear Klein-Gordon and Schrödinger equations. The common feature of all equations is the appearance of "soliton"-like solutions which are either stationary (in the case of Klein-Gordon and energy critical wave equations) or periodic in time (as in the Schrödinger case). These solitons are unstable, and amongst those the ground state is singled out, which has the lowest energy of all solitons. It has the property that the linearized operator which it gives rise to exhibits a single (and simple) negative eigenvalue. This negative mode produces one-dimensional stable and unstable manifolds, and there is also a center manifold of codimension two associated with the ground state. One of the main results for the subcritical case explained in the lectures is that the center-stable manifold appears as a surface of co-dimension one which separates a region of finite-time blowup in forward time from one which exhibits global existence and scattering to zero in forward time. Solutions which start from the center-stable manifold itself are also global and scatter to the ground state. The analysis takes place in the energy topology, and the solutions are restricted to have energies at most slightly above that of the ground state.

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

Besides the speakers and the organizers, there were 62 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.

The funds provided by the ESI were used to pay for the local expenses of the speakers, and of many of the students and post-docs among the participants. Many of the more senior participants used their own funds, and also provided funds for some of their students, which allowed us to have this large number of participants. It was also very helpful that all of the speakers agreed to fund the cost of their travel to Vienna on their own.

Invited Scientists: Llor Aermark, Mohammed Amayri, Miguel Ballesteros, Raphael Benguria, Gerhard Bräunlich, Bernhard Clark Musselman, Michael Damron, Giuseppe de Nittis, Jonas de Woul, Jürg Fröhlich, Andrea Goertsches, Andreas Groh, Jack Hanson, Christian Hainzl, Susanne Höllbacher, Helge Krüger, Marius Lemm, Thomas Lampart, Benjamin Loewe, Douglas Lundholm, Vieri Mastropietro, Edmund Menge, Phan Thanh Nam, Marcin Napiorkowski, Kim Petersen, Fabian Portmann, Florian Robl, Jimena Royo-Letelier, Rainer Ruder, Wilhelm Schlag, Robert Seiringer, Phil Sosoe, Stephen Tate, Fabio Toninelli, Alexandre Tomberg, Gerardo Daniel Valencia Martinez, Verena Von Conta, Johannes Von Keler, Matthias Westrich, Peter Windridge, Andreas Wöhr.

Rigorous Quantum Field Theory in the LHC Era

Organizer: Christian Jäkel (Cardiff University), Christoph Kopper (Ecole Polytechnique), Gandalf Lechner (Universität Wien)

Dates: September 21 - October 1, 2011

Budget: ESI €21.620,–

Preprints contributed: [2336], [2352]

Report on the programme

Quantum field theory (and especially the standard model) remains unchallenged when it comes to predicting the experimental data currently produced at the LHC. The aim of the programme "Rigorous Quantum Field Theory in the LHC Era" was to review and to discuss, what is known from a mathematical perspective about the standard model, its predictions for the LHC, the structural aspects underlying its formulations, and the mathematical problems encountered if one tries to give a precise mathematical meaning to the model. The wide scope of the programme allowed us to bring together senior experts working on different aspects, and it was a pleasure to see how discussions were reaching out over the borders often characteristic for modern, rather specialized research areas. We were also extremely pleased that so many young researchers were present, most of them supported by funding from outside.

The programme was attended by 45 participants, out of which 23 received financial support from the ESI. In total, 23 talks were given.

Topics discussed during the programme:

1. *Precision calculations for the LHC.* The starting point of this workshop was an up-to-date review of the experimental situation at the LHC, together with a review of the various aspects of LHC phenomenology, presented to us by Yves Sirois, Emery Sokatchev and Stefan Weinzierl.

2. *Gauge theories, especially QED and the standard model.* Various aspects of gauge theories were discussed in great detail, including infrared problems and (perturbative) renormalization. The list of participants working on this topic includes Abdelmalek Abdesselam, Detlev Buchholz, Thomas Chen, Jonathan Dimock, Wojciech Dybalski, Klaus Fredenhagen, Harald Grosse, Christoph Kopper, Pronob Mitter, Alessandro Pizzo, Katarzyna Rejzner, Yves Sirois, Emery Sokatchev, and Stefan Weinzierl.

3. *Constructive quantum field theory.* Various mathematically rigorous schemes have been developed to deal with the highly singular short distance behaviour of quantum field theories. The list of experts present at the workshop and working on this topic includes Abdelmalek Abdesselam, Jonathan Dimock, Arthur Jaffe, Christian Jäkel, Christoph Kopper, Jacques Magnen, Pronob Mitter, Alessandro Pizzo, Fabien Vignes-Tourneret.

4. *Algebraic constructive methods.* While traditional constructive field theory is tailored after the traditional perturbative approach to quantum field theory, new purely algebraic methods to construct interacting field theories do not start out from a classical Lagrangian field theory. It has yet to be seen, if these ideas will be relevant to the standard model, but intensive research is carried out by (among others) Henning Bostelmann, Detlev Buchholz, Daniela Cadamuro, Wojciech Dybalski, Harald Grosse, Albert Huber, Gandalf Lechner, Roberto Longo, Eric Morfa-Morales, Albert Much, Rainer Verch.

5. *Quantum field theory on curved space-time.* While the standard model itself does not include (quantum gravity), the quest for formulating the standard model on a curved space-time not only poses challenges, it also provides hints to what is really relevant within the standard model: the challenge is to formulate the standard model in terms of local quantities. This topic has found a lot of traction in recent years, and therefore played a prominent role during the workshop. The list of people interested in this topic includes Henning Bostelmann, Jacques Bros, Detlev Buchholz, Claudio Dapiaggi, Jonathan Dimock, Henri Epstein, Chris Fewster, Klaus Fredenhagen, Thomas-Paul Hack, Christian Jäkel, Roberto Longo, Eric Morfa-Morales, Ugo Moschella, Karl-Henning Rehren, Rainer Verch.

Account of the scientific talks presented during the workshop.

The clarification of the sector structure in quantum field theories with long-range forces (such as the electro-weak sector in the standard model) is a longstanding problem, and Detlev Buchholz provided substantial new insights into these questions in his the opening talk. Riccardo Guida presented some interesting bounds (uniform in all orders) for the perturbation theory of the massless Euclidean φ^4-theory and his talk was followed by that of Abdelmalek Abdesselam who explained in detail, also during a second session on Thursda), how to deal with massless quantum field theory over the reals and p-adics within the context of constructive quantum field theory.

The first day of the workshop was the day the official opening of the Research Centre Erwin Schrödinger (now as a part of the University of Vienna) took place. This gave the participants the opportunity and the privilege to listen to Fields Medal winner Wendelin Werner's talk on Random surfaces and their geometry.

On Thursday Jacques Magnen presented diagrammatic aspects for a group field theory model, while Thomas Chen discussed recent progress on mean field limits for interacting Bose gases. New ideas to construct interacting quantum field theories in a purely operator algebraic manner have turned out to be quite successful and Detlev Buchholz presented a second talk on this topic.

On Friday the emphasis changed and in front of a very large audience (which stretched far beyond the list of participants), Yves Sirois gave an exciting introduction to Higgs Boson(s) physics and what kind of results are expected experimentally at the TeV Scale in current experiments at the LHC. André Hoang had the difficult task to explain, how in detail soft-collinear effective theory a quantum field theory for jets at colliders allows to actually compute the theoretical predictions against which the experimental outcome will be judged. In the afternoon Emery Sokatchev showed few glimpses on hidden symmetries of scattering amplitudes. The final highlight of the first week was Arthur Jaffe's *Erwin Schrödinger Lecture* on his pioneering work (together with James Glimm and Thomas Spencer) in constructive quantum field theory and the role of renormalization theory in mathematics in general.

On Monday, Stefan Weinzierl provided some further insights into precision calculations for the LHC. Returning to QED, Wojciech Dybalski discussed inclusive cross-sections, while Alessandro Pizzo showed how one can avoid an infrared catastrophe in non-relativistic QED. Maxwell equations remained at the center of interest, when Claudio Dappiaggi focused on generalizations of QED to general curved space-times.

Karl-Henning Rehren started the series of lectures on Tuesday by explaining the AdS-CFT correspondence and the renormalization of interactions of fields with continuous mass. Conformal field theories were also central in Roberto Longo's contribution to the conference. He concentrated on thermal states and boundary QFT on the interior of the Lorentz hyperboloid. Chris Fewster addressed the question: What makes a theory of physics the same in all space-times? while Henning Bostelmann had a look at the characterization of local operators in factorizing scattering models.

The renormalization group according to Balaban is considered to be the most advanced method when dealing with gauge theories, and Jonathan Dimock was so kind to share his deep insights into Balaban's work with all participants. Pronob Mitter put emphasize on new ideas (called finite-range decompositions), which aim at eliminating cluster expansions, while applying renormalization group techniques.

Ugo Moschella, Jacques Bros and Henri Epstein confronted the audience with some unusual and interesting phenomena one might expect to encounter in an expanding de Sitter universe. Finally, Bert Schroer, the last speaker in the main program, concentrated on the origin of integrability in quantum field theory.

The final activity of the workshop was a *Young Researchers' Session*, and talks were contributed by Daniela Cadamuro (University of Göttingen), Katarzyna Rejzner (University of Hamburg), Christoph Köhler (University of Vienna) and Albert Much (University of Leipzig).

Final comments. The organizers received a very positive feedback from the participants concerning the impact of the programme on their research. During the workshop several new collaborations (some of them across the border lines of specialized research areas) were initiated and many old ones were continued or re-activated. In the near future a number of publications will appear as a direct result of the research conducted during the workshop.

Invited scientists: Abdelmalek Abdesselam, Sabina Alazzawi, Asao Arai, Henning Bostelmann, Jacques Bros, Detlev Buchholz, Daniela Cadamuro, Alan Carey, Thomas Chen, Claudio Dapiaggi, Jonathan Dimock, Wojciech Dybalski, Henri Epstein, Chris Fewster, Leander Fiedler, Klaus Fredenhagen, Harald Grosse, Riccardo Guida, Thomas-Paul Hack, Andre Hoang, Albert Huber, Arthur Jaffe, Christian Jäkel, Christian Köhler, Christoph Kopper, Gandalf Lechner, Roberto Longoa, Jacques Magnen, Pronob Mitter, Eric Morfa-Morales, Albert Much, Ugo Moschella, Alessandro Pizzo, Matthias Plaschke, Karl-Henning Rehren, Katarzyna Rejzner, Jan Schlemmer, Christian Schützenhofer, Yves Sirois, Emery Sokatchev, Michael Stiller, Rainer Verch, Fabien Vignes-Tourneret, Lena Wallenhorst, Stefan Weinzierl.

Algebraic versus Analytic geometry

Organizers: H. Hauser, (Vienna), J. Kollár (Princeton), J. Schicho (Linz), D. van Straten (Mainz)

Dates: November 19 - December 13, 2011

Budget: ESI € 14.630,– ; FWF proj. P21461 € 4.631,–

Report on the programme

Aims and scope

The research programme featured three topics with two speakers and one organizer each: Approximation Theorems and Arcs, Local Analytic Geometry, and Minimal Model Program. The programme consisted of two stages:

During the first stage (April-November 2011) the participants selected and prepared the research themes. The themes could be established theories one would like to learn or understand better, concrete examples and applications to be worked out, or genuine research problems. Every participant was invited to submit suggestions on questions, problems and theories she/he is particularly interested in.

In the second stage, the participants met at the ESI (November 19th - December 13th 2011) to present, exchange and discuss their contributions. The two or three speakers of each topic provided extended lectures on the topic, which were complemented by individual presentations and the problem sessions. There was plenty of time for informal discussion.

1. Artin Approximation and Arcs. Organizer: Guillaume Rond (Luminy)

The Artin Approximation Theorem and its extensions by Popescu and Spivakovsky are still relatively little known and understood in the mathematical community, despite their many applications. In particular, the theorem only asserts the existence of convergent or algebraic solutions, but does not give effective constructions or describe the entire set of solutions. Moreover, recent developments in CR-geometry show the need for an approximation theorem in a "mixed field case". The goal will be to revisit the various statements of the theorem, to examine their proofs and to search for a coherent understanding of varieties defined in power series spaces by algebraic equations. This gives a natural connection to arc spaces, which deal with the case of power series in one variable.

This was the first topic of the programme "Algebraic versus Analytic Geometry" and was held at ESI from November 19th to November 26th. During nine days there were 6 lectures sessions given by Dorin Popescu and 20 talks given by eminent researchers such as Lawrence Ein, Goulwen Fichou, Herwig Hauser, Shihoko Ishii, Krzysztof Kurdyka, Monique Lejeune-Jalabert, Adam Parusinski, Mark Spivakovsky, and many others.

There were in fact two related topics covered by this programme: "Artin Approximation" and "Arc Spaces". Dorin Popescu (Institute of Mathematics of the Romanian Academy) gave lectures about Artin Approximation (his lectures notes are available at `http://www.xxyyzz.cc/lectures_ATA.html`). D. Popescu has been one of the main specialists of the subject for the last 40 years. Apart of these lectures there should have been lectures on the second subject given by Johannes Nicaise (University of Leuven), but for personal reasons he had to cancel his participation few days before the beginning of the program.

At the same time, there were talks given by some of the participants. These talks were of several types. Goulwen Fichou (University of Rennes) and Shihoko Ishii (University of Tokyo) gave two talks each one about Arc Spaces to replace the lectures of J. Nicaise. Then there were several talks to present in some details specific topics that were not covered by the lectures. Moreover there were some talks to give a few details about some technical but classical points, these were aimed for students and non-specialists. Finally there were talks given by some of the participants to present their own research results in relation with the topics of the program.

The participants were very willing to make this programme a success in spite of the non-standard form of this meeting. Indeed, usually these kinds of meeting are intended to present the last new results about some topic. Here an effort was made to make sure that people in the room actually understood what was being explained. The warm atmosphere of ESI, the numerous blackboards and the possibility of having an office during this programme encouraged the participants to discuss and to share their points of view about the topics.

The material presented during this programme (lectures notes along with some notes of the talks) is available at `http://www.xxyyzz.cc/lectures_ATA.html`.

2. Local analytic geometry. Organizer: Eleonore Faber (Vienna)

P. Deligne introduced logarithmic differential forms as dual to the vector fields tangent to an analytic variety. K. Saito then developed the theory of free divisors, i.e., divisors, for which the module of logarithmic differential forms is free. This notion has been characterized geometrically by A. Aleksandrov, thus showing that it is a generalization or variation of the concept of normal crossings. This leads to the basic question how to characterize intrinsically normal crossings (both algebraic and analytically) by adding a suitable condition to freeness. The final goal is to define a significant invariant which measures the distance of a singularity from having normal crossings. This, in turn, would have substantial impact on the problem of the embedded resolution of singularities where one tries successively by suitable blowups to transform a singularity into a normal crossings scheme. Also, a constructive and effective criterion for checking normal crossings (without disposing of the decomposition into irreducible components) would be very desirable.

The workshop was organized in more flexible way than usual: there were two main lecture courses by L. Narváez (*Integrable logarithmic connections with respect to a cusp*) and by F. Castro (*Modules over the Weyl algebra and Bernstein–Sato polynomials*), complemented by exercise sessions and talks by the participants. The talks were not only about respective research results of the participants but also about topics and questions arising in vivid discussions during the workshop and connected to the lectures.

3. Minimal Model Program. Organizer: Niels Lubbes (Linz)

There is a unique smooth projective curve in each birational equivalence class of curves. For surfaces there are infinitely many smooth representatives in each birational equivalence class, but the relation between birational minimal models can be explicitly described. On higher dimensional varieties there are curves which can be contracted, called extremal rays. The Mori cone theorem characterizes the extremal rays as special rays on a cone of curves. For dimension three and higher it is necessary to allow mild singularities. After contracting an extremal ray, bad singularities may result. A way to fix this is to introduce flips.

In the lectures on this topic, the main concepts for the higher dimensional minimal model programme were introduced, discussing also the current state of the art (such as the existence and termination of sequences of flips) and constructive aspects: Is it possible the compute a minimal model for a threefold given by explicit equations? How can the MMP be applied to find interesting families of rational curves on surfaces or threefolds?

Every other day there was a lecture in the morning and time for informal talks in the afternoon. During the days in between there was time for the participants to discuss the lecture material and problems, which were proposed by participants on a wiki site, before the actual meeting.

The three lecturers Kenji Matsuki, Osamu Fujino and Paolo Cascini gave a series of lectures under the title “New outlook on Minimal Model Program”.

From the classical view point, the Minimal Model Programme was developed as a tool to prove the finite generation of the canonical ring as an ultimate goal. A couple of years ago the finite generation was proved by BCHM, establishing the most of the major ingredients for the Minimal Model Programme. More recently Cascini-Lazic came up with a much simpler inductive proof for the finite generation. Now the new outlook suggests and proposes to establish and complete the Minimal Model Programme to its full extent, not as a tool but as a consequence of the finite generation, turning the whole scheme upside down.

Invited Scientists: Takuro Abe, Alexander Aleksandrov, Marco Andreatta, Remi Arcadias, Rdiger Bodenseher, Nero Budur, Clemens Bruschek, Francisco J. Calderon Moreno, Junyan Cao Paolo Cascini, Alberto Castano Dominguez Ana-Maria Castravet, F.J .Castro-Jimenez, Helena Cobo, Laura Colmenarejo,

Graham Denham, Zofia Denkowska, Maciej P. Denkowski, Lorenzo Di Biagio, Alexandru Dimca, Lawrence Ein, Eleonore Faber, Andrea Fanelli, Goulwen Fichou, Enrica Floris, Claudio Fontanari, Osamu Fujino, Yoshinori Gongyo, Pedro Gonzalez Perez, Michel Granger, Helmut Hamm, Yoshishige Haraoka, Herwig Hauser, Shihoko Ishii, Hiraku Kawanoue, Masayuki Kawakita, Stefan Kirchmair, Krzysztof Kurdyka, Bernhard Lamel, Vladimir Lazic, Olivier Le Gal, Monique Lejeune-Jalabert, Li Li, Niels Lubbes, Kenji Matsuki, Nordine Mir, David Mond, Hussein Mourtada, Julio-Jose Moyano-Fernandez, Luis Narvaez, Andras Nemethi, Wenhao Ou, Adam Parusinski, Stefan Perlega, Camille Plenat, Peter Konstantinov Petrov, Dorin Popescu, Michel Raibout, Armin Rainer, Ana Reguera, Jean-Jacques Risler, Guillaume Rond, Josef Schicho, Mathias Schulze, Jiro Sekiguchi, Helene Syr, Manuel Jesus Soto Prieto, Mark Spivakovsky, Susumu Tanabe, Luca Tasin, Mihai Tibar, Uli Walther, Martin Weimann, Takehiko Yasuda, Sergey Yuzvinsky, Zhixian Zhu.

8th Vienna Central European Seminar on Particle Physics and Quantum Field Theory

Organizers: H. Hüffel, (Vienna)

Dates: November 25 - 27, 2011

Budget: ESI € 1.920,– (co-funding)

Report on the programme

The meeting took place at the Faculty of Physics of the University of Vienna in the "Christian-Doppler" - Lecture Hall, Strudlhofgasse 4, A-1090 Vienna, Austria from November 25 to 27, 2011. It was organized by Helmuth Hüffel, Faculty of Physics of the University of Vienna. The workshop provided stimulating interactions between leading researchers and promising junior physicists. A considerable number of junior scientists participated in this meeting and speakers were selected from among them. The innovative character of the meeting was especially important and scientific contacts and collaborations were enhanced. This year's theme was covered in experimental presentations on ALICE, ATLAS, CMS and LHCb; theoretical lectures addressed electroweak symmetry breaking, new physics at LHC, flavour physics, QCD, heavy ion physics, physics with ultracold neutrons, and cosmology. In addition, Nobel Laureate Frank Wilczek gave the Boltzmann Lecture 2011 of the Faculty of Physics, which was part of the programme.

The invited plenary lectures were as follows.

Experiment: Hannes Wessels (Münster): Heavy Ion Results from the ALICE Experiment. Michael Kobel (Dresden): Status and Physics at ATLAS. Gigi Rolandi (CERN): CMS status and physics. Jeroen Van Tilburg (Heidelberg): Status and physics at LHCb

Theory: Andrzej Buras (München): Flavour Physics in the LHC Era. Michael Ramsey-Musolf (Madison): Particle Physics with Ultracold Neutrons. Francesco Sannino (Odense): Electroweak Symmetry Breaking and New Physics for LHC. Geraldine Servant (CERN): Cosmology and the LHC. Urs Wiedemann (CERN): Heavy Ion Physics Giulia Zanderighi (Oxford): QCD and Tools for LHC. Frank Wilczek (MIT): Quantum Beauty: Real and Ideal.

Already in the course of the meeting the slide presentations of the lectures were placed on the webpage `http://www.univie.ac.at/vienna.seminar/2011/index.html` and are available for download.

Invited Scientists: Andrzej Buras, Michael Kobel, Michael Ramsey-Musolf, Gigi Rolandi, Geraldine Servant, Jeroen Van Tilburg, Urs Wiedemann, Giulia Zanderighi

Infinite Monster Groups

Organizer: G. Arzhantseva (Vienna), M. Sapir (USA)

Dates: December 12 - 21, 2011

Budget: ESI € 15.360.– ; ERC € 4.096,–

Report on the programme

The aim of the programme was to bring together both recognized experts and young mathematicians interested in various methods of constructing infinite groups with extreme properties. Topics included, but were not limited to, geometric, analytic, combinatorial, algorithmic, and computational aspects of the following major classes of infinite groups: Limits of groups with curvature (e.g. Burnside and Tarski monsters); Golod-Schafarevich groups; Limit groups in the sense of Sela (questions related to Tarski problem); Random groups; Infinite Kac-Moody groups; Infinite simple groups; Kähler groups; Thompson's groups.

The programme is the first organized event ever that gave a broad view on the phenomena of infinite monster groups. It was attended by 48 participants. It was begun by the prestigious Erwin Schrödinger Lecture given by Martin Bridson (Oxford) on "Finitely presented groups: geometry, decision problems, finite quotients, and monsters". The core of the programme was the workshop where 23 plenary talks were presented (see the list on `http://www.mat.univie.ac.at/~arjantseva/monster/`). There were 2 introductory lectures: "Asymptotic cones of finitely generated groups" by Denis Osin (Vanderbilt) and "Von Neumann algebras and l^2-invariants" by Andreas Thom (Leipzig), which were highly appreciated especially by young participants and by the specialists new to the subject. There were also a lively problem session, several informal blackboard sessions, and many group and pairwise discussions. All this showing that the research area on infinite monster groups is among the most active in geometric group theory!

It is impossible to summarize in a short report the richness and depth of the work and presentations. Here is a selected list of research topics the participants focused on. We also indicate some of new collaborations that were initiated during the programme.

1. *New properties of famous infinite monster groups.* Nowadays there are established theories and fundamental results on certain infinite finitely generated groups with exceptional properties such as Burnside-like groups and Tarski monsters. During the programme possible new viewpoints on such examples towards new structural results and more information on the geometric, analytic, and algorithmic properties of such groups war considered. For instance, the following topics were discussed:

– A link between the growth of an automorphism of the free group of rank r and its order as automorphism of the free Burnside group of rank r and large odd exponent n (R. Coulon, jointly with A. Hilion);

– Combinatorial properties of Engel relators, that is of Engel words in the free group considered as relators of group presentations (A. Juhasz, jointly with D. J. Collins). Such words appear in a work in progress by E. Rips, which aims at constructing a finitely generated n-Engel group for large enough n, which is not locally nilpotent;

– New types of finitely generated recursively presented groups G with undecidable word problem, called Dehn monsters. In fact, the word problem is so bad in these groups that there is no algorithmic way to produce an infinite set of pairwise distinct elements of G. The Golod-Shafarevich construction and immune sets from the classical recursion theory were used to build Dehn monsters (A. Myasnikov and D. Osin);

– A construction of a locally compact simple group with no lattices. Namely, the group of almost automorphisms of a d-regular tree does not admit lattices. This is the first such example among (compactly generated) simple locally compact groups (Sh. Mozes, jointly with U. Bader, P.-E. Caprace, and T. Gelander);

and still open problems on:

– A way to build a group with a cyclic subgroup of infinite index such that the number of finite cosets with respect to this subgroup is finite. The (non)-existence of such a group is a difficult question of M. Dunwoody (A. Muranov);

– Fixed point properties of certain (non-random) infinite monster groups (G. Arzhantseva and T. Toyoda) and small cancelation approaches to investigate whether or not the free Burnside groups have Property T (Y. Cornulier).

2. *Metric embeddings of spaces and groups into Hilbert and Banach spaces.* Such embeddings can be viewed as a geometric linearization of infinite finitely generated groups. Thanks to works of M. Gromov, G. Yu, G. Kasparov and others, the existence of so-called coarse embeddings leads to significant results on Baum-Connes, Novikov, Borel and other famous conjectures in topology and K-theory. The following topics were discussed:

– The first example of a metric space with bounded geometry which coarsely embeds into a Hilbert space, but is not coarsely amenable. This answers a long standing question (still open in case of a finitely generated group) and has interesting applications to C^*-algebras (G. Arzhantseva, E. Guentner, and J. Spakula);

– How coarse embeddability of so-called box spaces (certain metric spaces of bounded geometry associated with residually finite groups) into Hilbert space behaves under group extensions (A. Khukhro);

as well as new research directions on:

– Bi-Lipschitz embeddings of locally finite metric spaces into Hilbert spaces (V. Capraro);

– Constructions of non-amenable groups all of whose box spaces coarsely embeds into a Hilbert space (J. Spakula);

– Coarse embeddings of various groups related to Gromov's monster construction (G. Arzhantseva and J. Spakula).

3. *Groups acting on spaces with curvature, their limits and generalizations.* This includes generalizations of Gromov's hyperbolic groups and applications. The discussions were concerned with recent results on:

– Monster actions of free and hyperbolic groups (A. Ol'shanskii);

– Möbius structure on the boundary of hyperbolic groups (V. Schroeder);

– Groups with hyperbolically embedded subgroups (D. Osin, jointly with V. Guirardel, F. Dahmani);

– Residual finiteness of outer automorphism groups. Namely, various approaches for proving that such a group $Out(G)$ is residually finite, when G is a hyperbolic or a relatively hyperbolic group (A. Minasyan, jointly with G. Levitt);

and new promising methods to work on:

– Equationally definable subgroups of groups acting acylindrically on hyperbolic spaces (O. Kharlampovich, A. Myasnikov, and D. Osin);

– Conjugacy p-separability for finite index subgroups of right angled Artin groups (A. Minasyan, P. Zalesskii);

– The geometry of groups in connection with actions on infinite dimensional hyperbolic spaces (Y. Cornulier, T. Delzant).

4. *Geometric group theory and algebraic geometry.* This had both a direct meaning such as search for potential applications of geometric group theory to algebraic geometry and a group-theoretical interpretation such as the study of equations in groups. Among the results discussed were

– A description of definable subsets in a free non-abelian group F that follows from previous works on the Tarski problems (O. Kharlampovich and A. Myasnikov);

– A generalization of a classical theorem of Carlson and Toledo stating that any Zariski dense isometric action of a Kähler group on the real hyperbolic space of dimension at least 3 factors through a homomorphism onto a co-compact discrete subgroup of $PSL(2, \mathbf{R})$. A description of some exotic actions of $PSL(2, \mathbf{R})$ on infinite dimensional hyperbolic spaces and applications to the study of the Cremona group (T. Delzant);

and the discussions initiated new research on:

– Interesting features about the geometry of the Cremona group, which can be used to study the dynamical properties of its subgroups (Y. Cornulier);

– the Kähler groups of positive deficiency (T. Delzant and R. Strebel).

5. *L^2-invariants and profinite completetions.* These topics were considered, in particular, in the perspective of possible applications of geometric group theory to operator algebra and vise versa. We aimed to understand a relation between certain spectral properties of groups and profinite completions (H. Bradford), non-large (in the sense of Gromov) groups with infinite first Betti numbers (E. Fink), an entropy of algebraic actions and L^2-Reidemeister torsion (A. Felshtyn) as well as pro-p groups acting on pro-p trees (P. Zalesskii and W. Herfort). A recent progress on the entropy of certain algebraic dynamical systems and a relationship to l^2-torsion has raised a particular interest among the participants (A. Thom).

According to a short survey the participants filled out after the meeting, the programme was rated as of very high international standard and was greatly beneficial. The discussions were very productive and the atmosphere at the institute was very inspiring. Several participants have visited the ESI and met Vienna's mathematicians for the first time. We would also like to mention that 1/3 of all participants of this international programme were Vienna's mathematicians (both beginners and experts). In view of further collaborations, some of the international participants have planned to present their work in other research seminars (both at the Faculty of Mathematics and at the TU Wien).

Besides the support from ESI the programme was also finically supported by the ERC grant of Goulnara Arzhantseva "ANALYTIC" no. 259527 and by the Faculty of Mathematics of the University of Vienna.

Invited scientists: Miklos Abert, Goulnara Arzhantseva, Karl Auinger, Henry Bradford, Martin Bridson, Dietrich Burde, Valerio Capraro, Corina Gabriela Ciobotaru, Yves Cornulier, Remi B.G. Coulon, Thomas Delzant, Alexander Felshtyn, Gero Feudler, Elisabeth Fink, Martin Finn-Sell, Swjatoslaw Gal, Dominik Gruber, Roger Gomez Ortells, Wolfgang Herfort, Arye Juhasz, Olga Kharlampovich, Ana Khukhro, Joonhyung Kim, Benno Kuckuck, Ashot Minasyan, Wolfgang A. Moens, Shahar Mozes, Alexei Muranov, Alexei Miasnikov, Hokuto Morishima, Alexander Olshanskiy, Damian Osajda, Denis Osin, Liviu Paunescu, Jesse Peterson, Colin Reid, Bertrand Remy, Mark Sapir, Johannes Schleschitz, Viktor

Schroeder, Jan Spakula, Markus Steenbock, Ralph Strebel, Jacek Swiatkowski, Andreas Thom, Tetsu Toyoda, Guoliang Yu, Pavel Zalesskii.

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 lack of funding the programme had to be terminated by the end of 2010, but 4 fellows that had already been granted support stayed at ESI the first two months of 2011.

Junior Research Fellowships in 2011

Name	Gender	Duration	Nationality
Wojciech Krynski	male	01/01 - 28/02	Poland
Nora Seeliger	female	01/01 - 28/02	Germany
Mark Williamson	male	01/01 - 28/02	United Kingdom
Angelika Kroner	female	01/01 - 28/02	Austrian

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:

Kenneth Dykema (Texas A &M University), **Roland Speicher** (Universität des Saarlandes), Summer 2011: *Free Probability Theory*

Bruno Nachtergaele (UC Davis), Summer 2011: *Quantum Spin Systems. An introduction to the general theory and discussion of recent developments.*

Michael Baake (University Bielfeld), Summer 2011: *Spectral theory of dynamical systems and aperiodic order.*

Peter West (King's College, London), Summer 2011: *Symmetries of Strings and Branes.*

James Cogdell (Ohio State University, Columbus, USA), Winter 2011-12: *L-functions and functoriality.*

Visitors and Guest Speakers within the Senior Research Fellowship Framework:

Robert Sims (Univ. of Arizona), 31/05/2011 - 30/06/2011
Eman Hamza (Univ. of Cairo), 12/06/2011 - 24/06/2011
Sven Bachmann (UC Davis), 04/05/2011 - 14/05/2011
Christian Huck (Univ. Bielefeld), 03/05/2011 - 05/05/2011
Uwe Grimm (Milton-Keynes), 09/05/2011 - 14/05/2011, 23/06/2011 - 27/06/2011
Peter Zeiner (Univ. Bielefeld), 04/06/2011 - 12/06/2011
Rudolf Scharlau (Univ. Dortmund), 06/06/2011 - 12/06/2011
Jörg Thuswaldner (Univ. Leoben), 15/05/2011 - 17/05/2011
Peter Müller (LMU, München), 15/06/2011 -17/06/2011
Christoph Richard (Univ. Erlangen), 15/06/2011 - 17/06/2011
Ute von Wangenheim (Univ. Bielefeld), 21/06/2011 - 23/06/2011

Kenneth Dykema and Roland Speicher: Free Probability Theory

A course on free probability theory was given jointly by Dykema and Speicher. It was attended by visitors to the ESI, as well as some members of the local scientific community. In particular, members of the combinatorial group around Krattenthaler were frequent participants of the lectures and provided interesting feedback. The structure of the course was that Dykema first gave lectures over several weeks, for a total of 630 minutes, and then Speicher gave lectures of approximately the same duration.
Dykema's lectures aimed to introduce free probability theory and covered:

1. Noncommutative probability spaces and freeness
2. A crash course on C^*-algebras

3. Free convolution and the free central limit theorem
4. Free products of C^*-algebras and von Neumann algebras
5. Some freeness results for random matrices, and applications to von Neumann algebras
6. Elements of microstates free entropy

In Speicher's lectures, the main emphasis was put on the random matrix aspects and the combinatorial facet of free probability. In particular, the following topics were covered:

1. Wigners semicircle law and asymptotic freeness in random matrices
2. Free central limit theorem, free cumulants, and the combinatorial approach to the R-transform
3. Block matrices and operator-valued free probability theory
4. Elements of free Fisher information and corresponding maximization problems

In addition to the interesting workshops and lecture series, there were wide-ranging mathematical discussions in a less formal settings by visitors to the ESI. Indeed, in breaks between lectures and after lectures, often extending late into the evening, there were groups of researchers engaged in discussions at the many wonderful blackboards in the offices and hallways at ESI. Of course, these were valuable for the general enrichment of knowledge of the participants, and in some cases resulted in specific research results.

Discussions by Dykema with Benoit Collins, Hari Bercovici and Claus Koestler led eventually to specific research results that will appear in papers that are being written. Additionally, discussions with Gabriel Tucci led to an exciting research project on a difficult problem, but this has not yet led to publishable results.

Speicher worked extensively with Franz Lehner on a combinatorial approach to proving that the Gaussian distribution is infinitely divisible in the free sense. There exists an analytical proof of that fact, but despite many efforts a combinatorial understanding is still missing. During the ESI programme Speicher and Lehner isolated a new combinatorial description in terms of walks on the Young graph (consisting of Young diagrams). Interesting partial results could be achieved; further investigations in this direction will hopefully result in a combinatorial proof.

Bruno Nachtergaele: Quantum Spin Systems. An introduction to the general theory and discussion of recent developments.

Course. Quantum Spin Systems. An introduction to the general theory and discussion of recent developments.

The course met for nineteen two-hour sessions: 10 lectures, 6 exercise sessions (for which I had the assistance of Damian Drexler, a graduate student in the Department of Physics), 2 student presentations and a guest lecture by Professor Robert Sims (University of Arizona). There were about 20 participants in total.

The course consisted of two parts. In *Part I* we introduced the basic framework for the mathematical study of quantum spin systems in a form suitable for applications in condensed matter physics as well as in quantum information and computation theory. This included a survey of the main questions the theory aims to address, and a discussion of several important model Hamiltonians. Tutorials on necessary topics of a more technical nature (such as the basic facts of C^*-algebras) were also included as needed.

Part II provided an introduction to a number of topics in quantum spin systems that are the subject of active current investigation. Our primary focus was on recent developments in the study of so-called "gapped quantum phases". These are ground states of quantum lattice models which, in some cases, have a property referred to as *topological order*. Characterizing these gapped ground states is an important step to better understand the possibilities and challenges of implementing quantum computation and information processing with topological quantum ground state phases. Furthermore, the critical points separating distinct gapped phases describe quantum phase transitions, which have fascinating mathematical and physical properties. A case in point is the conjectured E_8 symmetry of the critical quantum Ising chain, experimental evidence for which was recently reported in the literature.

Research. I had three ESI-sponsored visitors during my stay: Eman Hamza (Cairo Univeristy), Robert Sims (University of Arizona), and Sven Bachmann (University of California, Davis). Each visited the ESI for an extended period of time and this resulted in productive collaborations. Based on results obtained during my stay, I co-authored four papers, which I briefly summarize below. Some other research started at the ESI continues and will likely lead to further publications in the future. I had very interesting discussions with many other visitors at the ESI and also with members of the Mathematics, Physics, and Chemistry departments of the University of Vienna. In particular, my current research on gapped ground state phases of quantum lattice systems is closely related to the activities of Frank Verstraete's group in the Department of Physics. I had stimulating discussions with several members of this group during my stay.

So far, work started or completed at the ESI resulted in the following four papers.

1. *Lieb-Robinson Bounds and Existence of the Thermodynamic Limit for a Class of Irreversible Quantum Dynamics*, Bruno Nachtergaele, Anna Vershynina, Valentin A. Zagrebnov, arXiv:1103.1122, appeared in *Entropy and the Quantum II*, Robert Sims and Daniel Ueltschi (Eds), Contemporary Mathematics (AMS), **552** (2011) 161–175. ESI preprint 2306.

In this work we prove Lieb-Robinson bounds and the existence of the thermodynamic limit for a general class of irreversible dynamics for quantum lattice systems with time-dependent generators that satisfy a suitable decay condition in space.

2. *Local Approximation of Observables and Commutator Bounds*, Bruno Nachtergaele, Volkher B. Scholz, Reinhard F. Werner, arXiv:1103.5663, to appear in Operator Theory: Advances and Applications (Birkhäuser), ESI preprint 2323.

In this paper we derive a basic estimate for conditional expectations that can be used as generalizations of the partial trace for quantum systems with an infinite-dimensional Hilbert space of states. Such estimate are an essential tool in applications of Lieb-Robinson bounds to the study of quantum lattice systems.

3. *Ferromagnetic Ordering of Energy Levels for $U_q(\mathfrak{sl}_2)$ Symmetric Spin Chains*, Bruno Nachtergaele, Stephen Ng, Shannon Starr, arXiv:1105.5264, to appear in Lett. Math. Phys., ESI preprint 2326.

In this paper Hamiltonians of quantum spin chains with $SU_q(2)$ invariant nearest neighbor interactions are regarded as a special class of $SU_q(2)$ invariants. We study positivity conditions that are sufficient for ferromagnetic ordering of the eigenvalues of the Hamiltonian, and show that the cone of nearest neighbor interactions satisfying the conditions is of maximal dimension. We use the graphical calculus developed in the works of Kauffman and Lins and Frenkel and Khovanov to proof new formulas relating different bases of the $SU_q(2)$ invariants.

4. *Product vacua with boundary states*, Bruno Nachtergaele and Sven Bachmann, arXiv:1112.4097, ESI preprint 2350.

In this work, we introduce a family of quantum spin chains with nearest neighbor interactions

that can serve to clarify and refine the classification of gapped quantum phases of such systems. The gapped ground states of these models can be described as a product vacuum with a finite number of particles bound to the edges. The numbers of particles, n_L and n_R, that can bind to the left and right edges of the finite chains serve as indices of the particular phase a model belongs to. All these ground states, which we call Product Vacua with Boundary States (PVBS) can be described as Matrix Product States (MPS). We present a curve of Hamiltonians connecting the AKLT model to its representative PVBS model, which has indices $n_L = n_R = 1$.

Preprints contributed: [2306], [2323], [2326], [2350]

Michael Baake: Spectral Theory of Dynamical Systems and Aperiodic Order

Research. My research activities during the time at ESI focused on three topics.

Mathematical Biology

The theory of recombination is an important part of modern population genetics. It owes a lot to contributions from people in Vienna, both past and present. My own interest stems from the observation that certain nonlinear equations can be solved in closed form. In this context, via regular meetings along the biomathematics seminar with Profs. R. Bürger, J. Hofbauer, A. von Haeseler and J. Hermission, new ideas have been exchanged. In particular, a cooperation has been substantiated with R. Bürger. As a concrete next step, there will be a research visit to Vienna by Dr. Ute von Wangenheim, most likely financed by a DFG grant.

Mathematical Physics

My main research interest is the theory of aperiodic order, which is the mathematical counterpart of quasicrystal research in physics and materials science. Quasicrystals were discovered by D. Shechtman in 1982, who received the 2011 Nobel Prize in Chemistry for it. During the time as a senior fellow, I concentrated on the spectral theory of diffraction, in particular of singular continuous type. This was done in cooperation with Prof. Uwe Grimm, who visited the ESI twice during the period. We managed to complete an extension of the Classic Thue-Morse example to an entire, infinite family of substitution systems.

Lattice Combinatorics

A third activity (of more algebraic nature) consisted in the continuation of previous work on the enumeration of sublattices with special features. The questions emerge from crystallography and materials science, and need tools from algebra and number theory for their solution. During my visit, the focus was on well-rounded sublattices of planar lattices. They are the lattices whose shortest non-zero vectors span ambient space. This was analysed in cooperation with Dr. Peter Zeiner, who graduated from TU Wien, and Prof. Rudolf Scharlau from Dortmund. Both visited, and we were able to formulate a classification result. The corresponding paper is still in preparation, but will be finished in 2012. Alongside, two meetings with discussions took place at TU Wien, with Prof. em. Peter Gruber.

Lectures and Seminars

Lecture: Spectral theory of aperiodic order

My weekly lecture concentrated on mathematical diffraction theory and its connection to the dynamical systems. Beyond the rather well-understood pure point case, also the more recent progress on continuous spectra was covered, with emphasis on the open Problem's in this direction.

Seminar: Dynamical systems and Applications

The seminar was planned as a guest and visitors seminar. Speakers included:

- Dr. Christian Huck (Bielefeld)
- Prof. Peter Müller (LMU München)
- PD Dr. Christoph Richard (Erlangen)
- Prof. Uwe Grimm (Open University, UK)
- Prof. Rudolf Scharlau (Dortmund)
- Dr. Ute von Wangenheim (Bielefeld)
- Dr Peter Zeiner (Bielefeld)
- Prof. Jörg Thuswaldner (Leoben)

Preprints contributed: [2317]

Peter West: Symmetries of Strings and Branes

Course. During my visit to the ESI in April-May 2010 I gave ten lectures on string symmetries. These included a discussion of electromagnetic duality symmetries, including the Dirac charge quantisation condition, continued with the exceptional symmetries that occur in the maximal supergravity theories and then the S, T and U dualities symmetries of string theory. I lectured from my forthcoming book on Strings and Branes that will be published by Cambridge University press in the coming months.

Research. During my stay I had extensive discussions with theoretical physicists at the Technical University in Wien. In particular with Andreas Braun on the role that the conjectured E_{11} symmetry might play in F theory. We have now appointed Andreas Braun as a postdoctoral fellow to start in October 2012 at King's College when we will continue this work. We had very many applications for this post and without the ESI fellowship, and my resulting visit to Wien, it is rather unlikely that we would have appointed Andreas Braun. Thus the ESI fellowship has lead to a period of prolonged research collaboration between King's college and Austrian physicists.

James Cogdell: L-functions and Functoriality

Course. The principle of functoriality is one of the central tenets of the Langlands program; it is a purely automorphic avatar of Langlands vision of a non-abelian class field theory. There are two main approaches to functoriality. The one envisioned by Langlands is through the Arthur-Selberg trace formula, and with the recent work of Ngô, Arthur, and others this is now becoming available. The second method is that of L-functions as envisioned by Piatetski-Shapiro and is based on the converse theorem for $GL(n)$. The overall purpose of the series of lectures was to develop and explain the L-function approach to functoriality. The course consisted of 12 lectures of 90 minutes each together with the accompanying question periods of 45 minutes each.

The first lecture covered the theory of modular forms and their L-functions, the classical $GL(2)$ theory, as developed by Hecke in the 1930's. This includes his original Converse Theorem. The modern theory of L-functions for $GL(n)$ builds on this work of Hecke, combined with interaction of local and global harmonic analysis as was initiated in Tate's thesis, where he recast Hecke's work on $GL(1)$ in terms of an adelic theory.

The second lecture began the adelic theory of automorphic representations for $GL(n)$, covering the basic definitions of cuspidal automorphic representations and their decomposition into local

representations. This decomposition is eventually responsible for the Euler product expansion of the L-functions. We then discussed the Fourier expansion for cusp forms on $GL(n)$, the role the existence and uniqueness of Whittaker models play in the $GL(n)$ theory, and finally the Multiplicity One Theorem on the multiplicity of a cuspidal automorphic representation in the automorphic spectrum of $GL(n)$.

Lectures 3 through 10 were spent on the theory of L-functions for $GL(n)$ and the twisted L-functions for $GL(n) \times GL(m)$. One begins with cuspidal automorphic representations π and π' on $GL(n)$ and $GL(m)$ respectively. First one writes down two families of Eulerian integrals, one for the cases $m < n$ and one when $m = n$, which have nice analytic properties: convergence, entire (meromorphic in the case $m = n$) continuation to the complex plane, bounded in vertical strips, and satisfying a functional equation as $s \mapsto 1 - s$. These integrals were modeled on those of Hecke ($m < n$) or Rankin and Selberg ($m = n$). One next shows that these families factor into a product of local integrals, as in Tate's thesis, and then analyses the local families. At the non-archimedean places, these integrals form a fractional ideal in the space of rational functions in q^{-s} and the generator of this ideal is the local L-function. At a place where the local representation is unramified, one can explicitly compute the local Euler factor using classical invariant theory for $GL(n, \mathbb{C})$. At the archimedean places, the theory is more complicated, but there is an analogous theory. Finally one combines the properties of the global integrals plus the analysis at the local places to to define $L(s, \pi \times \pi')$ as an Euler product and prove that it has "nice" analytic properties: convergence in a half plane, entire continuation (again meromorphic if $m = n$), is bounded in vertical strips and again satisfies a $s \mapsto 1 - s$ functional equation. As a consequence of the analysis of the poles in the $m = n$ case, one obtains an analytic proof of the Multiplicity One Theorem for $GL(n)$.

The tenth lecture was devoted to the Converse Theorem for $GL(n)$. This is roughly the statement that if one has a degree n-Euler product that is "nice" in that it and its twists have the same analytic properties that the L-function of a cuspidal representation of $GL(n)$ has, then in fact the Euler product is that of a cuspidal automorphic representation of $GL(n)$. The proof of this was given in the basic case, and, following Hecke's classical proof for $GL(2)$ given in the first lecture, it was obtained by inverting the process developed in lectures 3–9. Morally, this theorem says that any degree n Euler product that one expects to be nice must come from a automorphic representation, i.e., must be "modular".

The eleventh lecture was devoted to describing an arithmetic family of Euler products that are conjecturally nice, the Artin L-functions attached to an n-dimensional representation of a Galois group. In this lecture we surveyed the results of class field theory and then the contents of Artin's three papers on his non-abelian L-functions from 1923, 1930, and 1931.

In the final lecture we applied the "moral theorem" coming from the Converse Theorem to the conjecturally "nice" L-functions of Artin to motivate the global and local Langlands correspondences, which roughly state that n-dimensional local or global Galois representations should be locally or globally modular, i.e., attached to appropriate representations of $GL(n)$ in such a way that preserves their L-functions. This is Langlands' formulation of a "non-abelian class field theory". Next, we discussed how one would formulate such a Langlands correspondence for groups G other than $GL(n)$. Finally, putting all this together, we formulated the Langlands Functoriality Conjecture as a process of transferring local and automorphic representations of G to $GL(n)$ mediated by the local and global Langlands correspondences, that is, by L-functions. Finally we discussed how one would then use the Converse Theorem on $GL(n)$ as a tool for establishing cases of this Functoriality Cojecture; this is the aforementioned "L-function approach" to functoriality.

Research. During my stay at the ESI I worked on two projects.

The first project was with F. Shahidi (Purdue University) and T-L. Tsai (MPIM Bonn). While

at the ESI, I worked on our paper *Local Langlands correspondence for GL_n and the exterior and symmetric square ε–factors*. This project was begun before my residence at ESI, but the final work and the writing were done at ESI. Both Shahidi and Tsai were in residence at the ESI in the month of January 2012 as part of the "Automorphic Forms: Arithmetic and Geometry" programme. In this work, we show that the local Langlands correspondence for $GL(n)$ preserves both the exterior square and symmetric square L– and ε–factors. This is a measure of robustness of the local Langlands correspondence and hopefully will help us understand the local Artin ε–factors better. As part of this work, we established the local analytic stability of the exterior square γ-factor for supercuspidal representations $GL(n)$, a result of independent interest in the local theory of automorphic forms. Given the central location of the ESI within Europe, I took the opportunity of my ESI residence to travel and talk on this work at the ETH in Zurich, the EPFL in Lausanne, and the Rényi Institute in Budapest.

The second project was related to the history of mathematics. This projects dates from my participation in the meeting "Emil Artin – His Work and His Life" held at the ESI in January of 2006. For the accompanying volume on Artin I had prepared a paper *On Artin L-functions* based on my 2006 lecture. I have taken this time at ESI to revise this article. In particular I have now included much of the material that I discussed in the lecture on Artin L-functions in my SRF course.

Programme and Workshop Organization. My tenure as a SRF overlapped with the ESI Programme on Automorphic Forms: Arithmetic and Geometry Jan.3–Feb. 29, 2012. I was a co-organizer of this programme with C. Mœglin (Paris), G. Muić (Zagreb) and J. Schwermer (Vienna). The programme itself will be covered in a separate report for the year 2012. As this relates to my SRF tenure, since the SRF began before the programme I was an "on site" organizer, along with Schwermer, and was involved with decisions about cancellations, late invitations, and offices, etc. As mentioned above, during the first half of the programme my collaborators Shahidi and Tsai were in residence and we worked on our paper *Local Langlands correspondence for GL_n and the exterior and symmetric square ε–factors*. In particular, both Shahidi and Tsai gave talks on this work during the first Workshop (9–20 January 2012). Finally, I am happy to report that the students in my SRF course were regular attendees at the two Workshops associated with the Programme.

Seminars and colloquia

2011 01 13, J. Renn: “Schrödingers Weg zur Wellenmechanik”
2011 01 14, A. Zeilinger: “The Career of Schrödinger’s Entanglement from Philosophical Curiosity to Quantum Information”
2011 01 14, J. Fröhlich: “A Minimalist’s View of Quantum Mechanics, Eighty Five Years After Schrödinger’s ’Annus Mirabilis’”
2011 01 14, K. Whaley: “Quantum Coherence and Entanglement in Biology”
2011 01 14, M. Heiblum: “Neutral Modes - A New Family of Energy Carrier currentless States”
2011 01 14, O. Darrigol: “A few reasons why Louis de Broglie discovered Broglie’s waves and yet did not discover Schrödinger’s equation”
2011 01 14, W. Thirring: “Erwin Schrödinger: Personal Reminiscences”
2011 01 15, H. Kragh: “A Quantum Discontinuity: the Bohr-Schrödinger Dialogue”
2011 01 15, M. Bitbol: “Schrödinger’s translation scheme between (abstract) representations and facts: a re-flection on his late interpretation of quantum mechanics”
2011 01 15, P. Zoller: “Quantum Computing and Quantum Simulation with Quantum Opticla Systems”
2011 01 15, R. Car: “Quantum mechanics and hydrogen bonds”
2011 01 19, B. Helffer: “New examples of minimal partitions and open questions”
2011 01 19, L. Geisinger: “Two-term spectral asymptotics for the Dirichlet Laplacian and its fractional powers”
2011 01 19, M. Iversen: “Minimising Convex Combinations of Low Eigenvalues”
2011 01 19, U. Smilansky: “The nodal set and its boundary intersections”
2011 01 20, G. Vial: “Sum numerical computations for minimal partitions”
2011 01 20, M. van den Berg: “Heat flow and spectrum for regions with Brownian boundary”
2011 01 20, P. Freitas: “Spectra of spherically symmetric manifolds”
2011 01 21, J. Kennedy: “Counterexamples to the Nodal Line Conjecture”
2011 01 21, P. Gérard: “Inverse spectral problems for Hankel operators and completely integrable systems”
2011 01 21, P. Nam: “New bounds on the maximum ionization of atoms”
2011 01 21, T. Østergaard Sørensen: “Real analyticity away from the nucleus of pseudorelativistic Hartree-Fock orbitals”
2011 01 22, A. El Soufi: “On the uniform boundedness of the eigenvalues of non-homogeneous membranes and domains in manifolds”
2011 01 22, A. Pushnitski: “Asymptotics of Eigenvalue Clusters of the Perturbed Landau Hamiltonians”
2011 01 24, A. Kox: “The Debate between Erwin Schrödinger and Hendrik Lorentz on the Principles of Quantum Theory”
2011 01 24, B. Schörkhuber: “On linear stability of self-similar blow-up for co-rotational wave maps”
2011 01 24, G. Berkolaiko: “Nodal domains and spectral critical partitions on graphs”
2011 01 24, M. Loss: “Energy estimates for the random displacement model”
2011 01 24, R. Donninger: “Stable self-similar blow-up for co-rotational wave maps”
2011 01 24, S. Demirel: “Spectral estimates for quantum graphs”
2011 01 24, S. Terracini: “On some optimal partition problems”

2011 01 25, D. Yafaev: "Exponential Decay of Eigenfunctions of First Order Systems"
2011 01 25, H. Kovarik: "Spectral bounds for two-dimensional magnetic Schrödinger operators"
2011 01 25, P. Biernat: "Numerical simulations of blowup in the heat flow for harmonic maps"
2011 01 25, P. Bizoń: "Continuation beyond blowup in the heat flow for harmonic maps"
2011 01 25, R. Frank: "Nodal domain bounds for fractional Schrödinger operators and applications"
2011 01 25, V. Bonnaillie-Noel: "Nodal domains and minimal partitions"
2011 01 26, C. Lena: "Examples of nodal minimal partitions"
2011 01 26, N. Szpak: "Dynamics near the threshold for blowup in nonlinear Klein-Gordon equations"
2011 01 27, A. Rendall: "Self-similar collapse of collisionless matter"
2011 01 27, A. Rostworowski: "Numeriacl investigation of a perturbed AdS spacetime"
2011 01 27, J. Jalmuzna: "Focusing semilinear wave equations on the Schwarzschild spacetime"
2011 01 28, D. Kofron: "The Newtonian limit of spacetimes for accelerated particles and black holes"
2011 01 28, G. Avila: "Tensor deompositions with fast decay conditions at space-like infinity"
2011 01 28, M. Ansorg: "The interior of axisymmetric and stationary black holes: Numerical and analytical studies"
2011 01 28, M. Eckstein: "The Black Saturn solution"
2011 01 28, M. Scholtz: "On asymptotically flat solutions of Einstein's equations periodic in time"
2011 01 28, N. Gurlebeck: "A Generalization to Chandrasekhar's & Elbert's 1-PN Dedekind ellipsoids"
2011 01 28, R. Meinel: "On the black hole limit of rotation discs and rings"
2011 01 28, S. Szybka: "Stable causality of the Pomeransky-Senkov black holes"
2011 01 28, W. Simon: "Criteria for finite extent of stationary perfect fluids in Newtonian theory"
2011 01 29, A. Szereszewski: "D-dimensional metrics with D-3 symmetries"
2011 01 29, I. Racz: "On the topology of strictly stable condimension two surfaces"
2011 01 29, J. Grant: "Monotonicity theorems for null cones"
2011 01 29, J. Kijowski: "Quasi-local character of gravitational energy"
2011 01 29, L. Szabados: "On quasi-local charges and Newman-Penrose type quantities in Yang-Mills theories"
2011 01 29, M. E. Gaspar: "On the dynamics of relativistic multi-layer spherical shell systems"
2011 01 29, N. Drozd: "Evolution of gravitational field as an infinite dimensional Hamiltonian system"
2011 01 29, P. Mach: "From ultrarelativistic jets to a hydrodynamical Riemann problem"
2011 01 29, S. Aksteiner: "Linearized gravity on type D backgrounds"
2011 01 31, A. Rennie: "Nonunital Index formulas"
2011 01 31, V. Gayral: "Noncompact noncommutative Geometries"
2011 02 01, F. Gesztesy: "Index regularizations and the Witten index"
2011 02 01, F. Gesztesy: "The index formula and the spectral shift function for relatively trace class perturbations"
2011 02 01, M. Lesch: "Chern-Cones character for manifolds with boundary"
2011 02 02, A. Pushnitski: "Scattering matrix and the spectral theory of discontinuous functions of self-adjoint operators"
2011 02 02, F. Sukochev: "Relatively bounded and relatively trace class perturbations"
2011 02 02, Y. Tomilov: "Fredholm index and hyperbolicity"
2011 02 14, M. Anshelevich: "Convolution semigroups with linear Jacobi parameters"
2011 02 14, M. Bozejko: "New characterisation of free Meixner processes"
2011 02 14, O. Arizmendi: "k-divisble Non-Crossing Partitions and Free Probability"
2011 02 14, R. Speicher: "Combinatorial aspects of free probability 1"
2011 02 14, V. Feray: "Characters of symmetric groups, free cumulants and a combinatorial Hopf algebra"
2011 02 15, H. Bercovici: "On sums and products in finie factors"
2011 02 15, M. Brannan: "Approximation properties for free orthogonal and free unitary quantum groups"
2011 02 15, R. Lenczewski: "Matricial R-Transform"

2011 02 15, R. Speicher: “Combinatorial aspects of free probability 2”
2011 02 15, T. Hasebe: “On Cauchy distributions in non-commutative probability”
2011 02 16, C. Köstler: “Noncommutative independence in the infinite braid and symmetric group”
2011 02 16, F. Götze: “Asymptotic Expansions in the Free Central Limit Theorem”
2011 02 16, J. Loday: “Generalized Hopf algebras and operads”
2011 02 16, P. Sniady: “Free cumultants in representation theory”
2011 02 17, C. Mazza: “B-Series, Schwinger-Dyson Equations and Wigner Processes”
2011 02 17, C. Sattlecker: “Free log-normal distribution and confluent hypergeometric series”
2011 02 17, F. Lehner: “The normal law, free probability, and a Hopf algebra of rooted binary trees”
2011 02 17, R. Speicher: “Combinatorial aspects of free probability 3”
2011 02 17, T. Cabanal-Duvillard: “A generalization of a result of Marchenko & Pastur, providing a family of Bercovici-Pata bijections”
2011 02 18, K. Dykema: “An application of asymptotic freeness to soficity of groups”
2011 02 18, M. Dolcega: “Colorings of bipartite graphs and polynomial functions on the set of Young diagrams”
2011 02 18, R. Speicher: “Combinatorial aspects of free probability 4”
2011 02 21, C. Krattenthaler: “Generalized non-crossing partitions for reflection groups and cyclic sieving”
2011 02 21, E. Redelmeier: “Second-order Freeness in the Real Case”
2011 02 21, M. Aguiar: “Infinitesimal Bialgebras 1”
2011 02 21, T. Banica: “Probabilistic aspects of free quantum groups”
2011 02 22, C. Brouder: “Noncommutative Feynman graphs and Hopf algebra cohomology”
2011 02 22, L. Pastur: “Laws of Fluctuations for Spectral Statistics of Random Matrices”
2011 02 22, M. Aguiar: “Infinitesimal Bialgebras 2”
2011 02 22, M. Mastnak: “Bialgebras and free multiplicative convolution”
2011 02 22, M. Popa: “Non-commutative functions and some of their applications in free probability”
2011 02 23, A. Nica: “On the C*-algebra of the Fock space representation for the q-commutation relations”
2011 02 23, D. Evans: “Modular invariants, subfactors ans twisted equivariant K-theory”
2011 02 23, F. Patras: “Noncommutative Spitzer identities”
2011 02 23, M. Aguiar: “Infinitesimal Bialgebras 3”
2011 02 23, N. Muraki: “A certain q-interpolation between tensor and free independence”
2011 02 24, C. Vargas: “Different sized Haar-unitaries arising from random matrix models”
2011 02 24, G. Chystyakov: “Infinitely divisible approximations of$n$-fold free convolutions”
2011 02 24, I. Krolak: “General commutation relations - properties of associated algebras and Ornstein-Uhlenbeck semigroup”
2011 02 24, M. Aguiar: “Infinitesimal Bialgebras 4”
2011 02 24, T. Gannon: “The search for the exotic”
2011 02 25, J. Wang: “A new approach to the monotone central limit theorem”
2011 02 25, M. Gordin: “Formal and Analytic Groups Related to Free Probability”
2011 03 04, E. Kowalski: “Equidistribution for local and global arithmetic objects”
2011 03 04, E. Welzl: “When Conflicting Constraints Can be Resolved - the Lovász Local Lemma and Satisfiability”
2011 03 04, G. Wüstholz: “Perioden”
2011 03 04, M. Burger: “On discrete subgroups of Lie groups: geomety, arithmetic and combinatorics”
2011 03 04, P. Biran: “Symplectic topology in the Large: from Morse to Foer & Beyond”
2011 03 04, T. Riviere: “Conservation laws and Noether’s Theorem in the absence of Symmetry”
2011 03 07, G. Racher: “Injective modules and amenable groups”
2011 03 14, G. Fendler: “Remarks on the regular C*-algebras of non-amenable Coxeter groups”
2011 03 28, E. Candellero: “Asymptotic behaviour of Random Walks on Free Products of Groups”
2011 03 28, L. Gilch: “Branching Random Walks on Free Products of Groups”

2011 03 29, P. Zwiernik: "Markov tree models and L-cumulants"
2011 04 05, M. Josuat-Verges: "Moments of orthogonal polynomials, and the normal ordering problem"
2011 04 05, R. Johnson: "Propagation of very long water waves, with applications to tsunamis"
2011 04 06, D. Group: "On the mathematics of tsunamis"
2011 04 07, O. Mustafa: "On isolated vorticity regions beneath the water surface"
2011 04 11, P. Soltan: "An application of property (T) for discrete quantum groups"
2011 04 11, S. Belinschi: "Convolution semigroups for operator valued distributions"
2011 04 11, S. Thorbjornsen: "Asymptotic expansions for GUE and Wishart random matrices"
2011 04 11, T. Banica: "Probabilistic aspects of free quantum groups"
2011 04 12, C. Donati-Martin: "Truncations of Haar distributed matrices and bivariate Brownian bridge"
2011 04 12, H. Cheballah: "Gog, Magog and Schützenberger Involution"
2011 04 12, P. Di Francesco: "The Proof of the ASM-DPP Conjecture"
2011 04 12, R. Vergnioux: "Path cocycles in quantum Cayley trees and L^2-cohomology"
2011 04 12, T. Banica: "Probabilistic aspects of fre quantum groups"
2011 04 13, D. Shlyakhtenko: "Planar algebras and free Probability"
2011 04 13, P. Zinn-Justin: "Planar algebras and Potts model on rando lattice"
2011 04 14, M. Bozejko: "Deformed Fock spaces, Hecke operators and non-commutative Levy processes for generalizes "anyonic" statistics (with E. Lytvynov and J. Wysoczanski)"
2011 04 14, N. Alexseev: "Genus expansion for some ensembles of random matrices"
2011 04 14, P. Biane: "Brownian motion on matrices"
2011 04 14, S. Curran: "On the symmetric enveloping algebra of planar algebra subfactors"
2011 04 14, T. Banica: "Probabilistic aspects of free quantum groups"
2011 04 15, C. Male: "The norm of polynomials in random and deterministic matrices"
2011 04 15, F. Radulescu: "A quantum double for Hecke operators, Ramanujan Petersson Conjectures and Free Probability"
2011 04 15, M. Nowak: "Multiplication law and S-transform for non-hermitian random matrices"
2011 04 15, T. Banica: "Probabilistic aspects of free quantum groups"
2011 04 15, V. Gerdjikov: "Modelling the soliton interactions of the nonlinear Schrödinger equations"
2011 04 15, Y. Dabrowski: "Applications of free SDEs to vaon Neumann algebras of q-gaussian variables"
2011 04 18, D. Voiculescu: "Araound the free Riemann sphere and duality for infinitesimal bialgebras"
2011 04 18, F. Benaych-Georges: "Finite rank perturbations of random matrices and free probability theory"
2011 04 18, J. Williams: "Decomposition and Tightness in Free Probability"
2011 04 18, R. Ivanov: "Multi-component generalizations of the Camassa-Holm equation"
2011 04 18, S. Woronowicz: "Simplified $E(2)$ quantum group"
2011 04 18, U. Franz: "Symmetries of Levy processes on compact quantum groups"
2011 04 19, D. Voiculescu: "Around the free Riemann sphere and duality for infinitesimal bialgebras"
2011 04 19, M. Capitaine: "Free subordination property and deformed matricial models"
2011 04 19, M. Junge: "Martingales with continuous time and application to brownian motion and dilation"
2011 04 19, N. Blitvic: "Chords, Norms, and q-Commutation Relations"
2011 04 19, Y. Ueda: "On free product von Neumann algebras"
2011 04 20, A. Tikhomirov: "Limit theorems for spectrum of products of large random matrices"
2011 04 20, D. Voiculescu: "Around the free Riemann sphere and duality for infinitesimal bialgebras"
2011 04 20, G. Tucci: "Random Vandermonde Matrices and Covariance Estimates"
2011 04 20, H. Maassen: "Entanglement of Werner states: greatest cross norm and immanent inequalities"
2011 04 20, L. Molinet: "Sharp ill-posedness results for the KdV and mKdV equation on the torus"
2011 04 21, A. Nica: "Convolution powers in operator-valued framework"
2011 04 21, B. Collins: "Random matrices, representations of $GL(n)$ and free probability of higher or-

der”
2011 04 21, C. Köstler: “Noncommutative independence from characters of the infinite symmetric group”
2011 04 21, M. Anshelevich: “Two-state free Brownian motions”
2011 04 21, N. Demni: “Kanter random variable and positive free stable laws”
2011 04 26, M. Wunsch: “Conservative solutions and the geometry of the two-component Hunter-Saxton system”
2011 04 28, R. Johnson: “On the Camassa-Holm and Korteweg-de Vries hierarchies”
2011 05 03, N. Euler: “Multipotentialisation of Evolution Equations and the Converse Problem”
2011 05 05, H. Holden: “On the Nonlinear Variational Wave Equation”
2011 05 10, K. Grunert: “Stability of solutions of the Camassa-Holm equation”
2011 05 12, H. Segur: “Tsunamis”
2011 05 17, C. Sulem: “Water waves over a rough bottom in the shallow water regime”
2011 05 17, J. Saut: “Remarks on the Cauchy problem for Boussinesq systems”
2011 05 17, M. Groves: “Existence and stability of fully localized three-dimensional gravity-capillary solitary water waves”
2011 05 17, N. Totz: “A Rigorous Justification of the Modulation Approximation to the 2D Full Water Wave Problem”
2011 05 17, V. Duchêne: “A nonlinear approach to the dead-water phenomenon”
2011 05 17, V. Hur: “Regularity vs. Blowup for surface water waves” 2011 05 18, A. Matioc: “On stratified steady periodic water waves with linear density distribution and stagnation points”
2011 05 18, B. Matioc: “Existence and regularity results for stratified water waves”
2011 05 18, D. Lannes: “A stability criterion for two-fluid interfaces”
2011 05 18, E. Wahlén: “Existence and stability of solitary water waves with weak surface tension”
2011 05 18, P. Germain: “Global existence for water waves”
2011 05 19, A. Nachbin: “Reduced water wave models with highly variable topography”
2011 05 19, H. Segur: “Surface waves on deep water”
2011 05 19, J. Escher: “Regularity of rotational waves”
2011 05 19, P. Guyenne: “A Hamiltonian approach to nonlinear modulation of water waves”
2011 05 19, T. Iguchi: “A mathematical analysis of tsunami generation in shallow water due to seabed deformation”
2011 05 19, T. Kano: “Water waves KdV hierarchy III”
2011 05 20, K. Becker: “Disk amplitudes, picture changing and space-time actions”
2011 05 24, G. Burton: “Rearrangement of vorticity and surface waves”
2011 05 26, D. Ionescu-Kruse: “Elliptic and hyperelliptic functions describing the particle motion beneath small-amplitude water waves with constant vorticity”
2011 05 31, M. Umeyama: “PIV and PTV measurements for progressive waves with a stedy current”
2011 05 31, R. Ivanov: “Two-componetn Camssa-Holm equation in the models of shallow water waves with vorticity”
2011 05 31, R. Johnson: “Models for the formation of a critical layer in water-wave propagation”
2011 05 31, W. Strauss: “Waves with Discontinuous Vorticity”
2011 06 01, B. Kolev: “On the geometrical structure of certain equations of hydrodynamical type”
2011 06 01, D. Clamond: “Direct numerical simulation on fully nonlinear surface waves”
2011 06 01, E. Varvaruca: “Global bifurcation of steady periodic water waves with constant vorticity”
2011 06 01, J. Escher: “Regularity of rotational water waves”
2011 06 10, D. Pelinovsky: “Global existence and wave breaking in the short-pulse and Ostrovsky-Hunter equations”
2011 06 14, I. Ghiba: “Homogeneous and inhomogeneous plane waves in elastic materials with voids”
2011 06 16, R. Sims: “Automorphic Equivalence within Gapped Phases of Quantum Lattice Systems”
2011 06 20, M. Becker: “Heterotic fluxes, where do we stand?”
2011 06 20, R. Zucchini: “A heterotic sigma model with novel target geometry”
2011 06 20, T. Rahn: “Landscape study of target space duality of (0,2) heterotic string models”

2011 06 21, I. Melnikov: "Tracking massless singlets in heterotic compactifications"
2011 06 21, J. McOrist: "The E_6 — SO(10) Higgs mechanism in the linear sigma model"
2011 06 21, J. Vanden-Broeck: "Solitary waves with oscillatory tails"
2011 06 21, S. Groot Nibbelink: "Anomaly cancellation in (0,2) heterotic orbifold resolutions"
2011 06 21, S. Sethi: "Linear Sigma Models with Torsion"
2011 06 22, J. Distler: "Quantized Fayet-Iliopoulos terms in N=1 supergravity"
2011 06 22, M. Tan: "A quasi-topological (0,2) heterotic B-Model, the mirror chiral de Rham complex, and twisted generalized mirror symmetry"
2011 06 22, R. & Eric Sharpe: "Quantum sheaf cohomology I"
2011 06 22, R. & Eric Sharpe: "Quantum sheaf cohomology II"
2011 06 22, U. von Wangenheim: "Single-crossover recombination and ancestral recombination trees"
2011 06 23, A. Adams: "Linear sigma models with torsion"
2011 06 24, A. Degeratu: "Invariants of elliptically fibered Calabi-Yau 3-folds"
2011 06 24, E. Kartashova: "Formation of energy cascades in turbulent water wave systems"
2011 06 28, M. Stiassnie: "Tsunami calculations"
2011 07 04, A. Fokas: "A unified and effective method for integrable nonlinear PDEs"
2011 07 04, A. Sergyeyev: "Recursion operators for dispersionless integrable systems in any dimension"
2011 07 04, B. Konopelchenko: "Harrison cohomology and integrable systems for the hyperelliptic subsets in Birkhoff strata of the Sato Grassmannian"
2011 07 04, B. Pelloni: "Boundary value problems for a nonlinear elliptic PDE: the elliptic sine-Gordon equation"
2011 07 04, H. Chen: "Long-wave limit of periodic solutions of nonlinear wave equations"
2011 07 04, I. Hitzazis: "Initial-boundary problems for integrable nonlinear PDEs"
2011 07 04, I. Nenciu: "The periodic Ablowitz-Ladik equation and Floquet CMV matrices"
2011 07 04, J. Bona: "Systems of nonlinear, dispersive wave equations"
2011 07 04, J. Eckhardt: "The isospectral problem of the Camassa-Holm equation"
2011 07 04, J. Lenells: "Boundary value problems for the Ernst equation"
2011 07 04, K. Grunert: "A Lipschitz metric for the Camassa-Holm equation"
2011 07 04, M. Cafasso: "Two transitions between the Pearcey and the Airy process"
2011 07 04, Y. Do: "Oscillatory Riemann-Hilbert problems and stationary phase"
2011 07 05, A. Constantin: "The hydrodynamical relevance of the Camassa-Holm and Degasperis-Procesi equations"
2011 07 05, A. Minakov: "Long-time behavior of the solution to the mKdV equation with the step like initial data"
2011 07 05, A. Moro: "Thermodynamic phase transitions and shock singularities"
2011 07 05, A. Rybkin: "The KdV equation, the Titchmarsh-Weyl m-function and Hankel operators"
2011 07 05, A. Sakhnovich: "Weyl theory, inverse spectral transform, and initial-boundary value problems for integrable equations"
2011 07 05, A. Soshnikov: "Random matrices: finite rank deformations and fluctuations of matrix entries of regular functions"
2011 07 05, H. Holden: "On the nonlinear variational wave equation"
2011 07 05, J. Baik: "Complete matchings and random matrix theory"
2011 07 05, J. Michor: "On the spatial asymptotics of solutions of the Ablowitz-Ladik hierarchy"
2011 07 05, J. Szmigielski: "On an inverse spectral problem associated to a two-potential generalization of the Degasperis-Procesi equation"
2011 07 05, K. Louis: "The integrability and the magnetization dynamics of weak ferro and antiferromagnets"
2011 07 05, P. Miller: "Fluxon condensates and the semiclassical sine-Gordon equation"
2011 07 05, T. Grava: "Universality in Hamiltonian PDEs"
2011 07 06, A. Boutet de Monvel: "Long-time dynamics of step-like data for NLS+"
2011 07 06, A. Kuijlaars: "Multiple orthogonal polynomials in the normal matrix model"

2011 07 06, D. Shepelsky: "The short-wave model for the Camassa-Holm equation: the Riemann-Hilbert approach"
2011 07 06, E. Sorkin: "Critical collapse of axisymmetric gravitational waves"
2011 07 06, H. Ringström: "Stability and topology of some models of the universe"
2011 07 06, R. Srinivasan: "Burgers turbulence, kinetic theory of shock clustering, and complete integrability"
2011 07 07, A. Mikikits-Leitner: "Long-time asymptotics of perturbed finite-gap Korteweg-de Vries solutions"
2011 07 07, C. Kalla: "Algebro-geometric solutions to the multi-component NLS equation: a theoretical and numerical description"
2011 07 07, C. Wu: "On Hamiltonian Perturbations of a Class of Evolutionary PDEs"
2011 07 07, D. Mantzavinos: "Applications of complex analysis to initial-boundary value problems"
2011 07 07, D. Masoero: "Some results concerning the semiclassical limit of KdV before the gradient catastrophe"
2011 07 07, D. Wang: "Hermitian matrix model with spiked external source: universality and new discoveries"
2011 07 07, F. Gesztesy: "On a generalization of the spectral problem underlying the Camassa-Holm hierarchy"
2011 07 07, H. Lundmark: "Orthogonal and biorthogonal polynomials in the theory of peakon equations"
2011 07 07, I. Egorova: "Inverse scattering transform for the KdV and Toda equations with steplike finite-gap backgrounds"
2011 07 07, P. Van Moerbeke: "From longest increasing sequences of random permutations to the Tacnode Process"
2011 07 07, R. Quispel: "Discrete Integrable Systems"
2011 07 07, S. Kamvissis: "Stability of the periodic Toda lattice"
2011 07 07, V. Enolski: "On the charge three cyclic monopole"
2011 07 11, A. Derdzinski: "Two-jets of conformal fields along their zero sets, in any metric signature"
2011 07 11, B. Warhurst: "Ultrarigid tangents of sub-Riemannian nilpotent groups"
2011 07 11, D. The: "The Lagrangian Grassmannian, hyperbolic PDE, and G_2"
2011 07 11, M. Dunajski: "G_2-structures and twistor theory"
2011 07 11, M. Eastwood: "Conformal foliations and CR geometry"
2011 07 12, C. Frances: "Essential singularities for higher dimensional conformal maps"
2011 07 12, J. Merker: "Effective Cartan-Tanaka connections on C^6-smooth strongly pseudoconvex hypersurfaces M^3 in C^2"
2011 07 12, M. Hammerl: "Holonomy-reductions of Cartan connections"
2011 07 12, O. Biquard: "Einstein metrics and parabolic geometries"
2011 07 12, P. Juhl: "Explicit formulas for GJMS-operators and Q-curvatures"
2011 07 12, V. Matveev: "Conformal and isometric transformations of Finsler manifolds: Wang theorem, Matsumoto question, Deng-Hu conjecture, conformal invariants of finsler metrics and Lichnerowicz-Obata conjecture"
2011 07 13, A. Taghavi-Chabert: "The Goldberg-Sachs theorem in higher dimensions"
2011 07 13, C. Luebbe: "Predicting / prescribing the location of conformal infinity"
2011 07 13, J. Case: "Quasi-Einstein metrics and the tractor calculus"
2011 07 13, M. Markowitz: "Intrinsic Pseudodistances for Parabolic Geometries"
2011 07 13, M. Mars: "On the constraint equations for general hypersurfaces"
2011 07 13, P. Blue: "Decay for the Maxwell field outside a slowly rotating Kerr black hole"
2011 07 13, R. Graham: "Ambient extension of parallel tractors"
2011 07 13, S. Krysl: "First order operators in projective contact geometry - a classification"
2011 07 14, B. McKay: "Hartogs extension theorem for parabolic geometries"
2011 07 14, P. Nurowski: "An analog of selfduality in dimension nine"

2011 07 14, R. Gover: "Projective BGG equations, algebraic sets, and compactifications of Einstein geometries"
2011 07 14, T. Barbot: "Spacetimes with Particles"
2011 07 14, V. Zádník: "On split signature conformal metrics induced by half-dimensional projective structures"
2011 07 15, B. Doubrov: "Conformal, symplectic and G_2 structures on solution spaces of ODEs"
2011 07 15, I. Zelenko: "Tanaka prolongation and symplectification procedure for filtered structures on manifolds"
2011 07 15, J. Alt: "Some locally transitive actions on the Moebius sphere related to conformal holonomy"
2011 07 15, N. Ó Murchadha: "Scaling the extrinsic curvature in the gravitational initial data: Generating trapped surfaces"
2011 07 18, A. Cap: "Introduction to Cartan geometries"
2011 07 18, C. Frances: "The Ferrand-Obata theorem for rank-1 parabolic geometries"
2011 07 18, J. Slovák: "Distinguished curves in Cartan geometries"
2011 07 18, K. Melnick: "Gromov-Zimmer theory of rigid geometric structures"
2011 07 18, K. Neusser: "On automorphism groups of certain types of vector distributions"
2011 07 18, V. Matveev: "Symmetries of projective or h-projective structure of a metric"
2011 07 19, A. Zeghib: "Kähler manifolds with big automorphism group"
2011 07 19, D. Constantine: "Compact Clifford-Klein forms and group actions"
2011 07 19, R. Feres: "Random Dynamics and spectrum of classical mechanical systems with partial information"
2011 07 19, S. Dumitrescu: "Locally homogeneous rigid geometric structures"
2011 07 20, C. Rossi Salvemini: "Globally hyperbolic conformally flat maximal spacetimes"
2011 07 20, D. Ruiz: "Affine deformations of hyperbolic structures and the Margulis invariant"
2011 07 20, G. Manno: "Projectively homogeneous metrics on 2-dimensional manifolds"
2011 07 20, I. Kath: "$G_2(2)$-structures on indefinite symmetric spaces"
2011 07 20, J. Michel: "Higher symmetries of Laplacian and quantization"
2011 07 20, K. Mann: "Global fixed points for groups acting on the plane"
2011 07 20, R. Gover: "Conformal tractors and infinitesimal automorphisms: An introduction"
2011 07 20, W. Lim: "Dynamics near spacelike singularities are more inhomogeneous than conjectured by BKL"
2011 07 21, D. Alekseevskiy: "Classification of homogeneous Lorentzian manifolds of a semisimple Lie group"
2011 07 21, G. Holzegel: "Stability problems for asymptotically AdS black holes"
2011 07 21, M. Dafermos: "Rapidly rotating and extremal black holes"
2011 07 21, Y. Kamishima: "Lorentzian similarity manifolds"
2011 07 22, F. Kassel: "Geometry and spectra of complete AdS^3-manifolds"
2011 07 22, L. Marquis: "Finite volume quotients of Hilbert geometries"
2011 07 27, H. Friedrich: "On conformal structures of asymptotically flat, static vacuum data"
2011 07 27, J. Valiente Kroon: "Geometric invariants for black hole spacetimes"
2011 08 02, S. Lau: "Fast Waveform Extraction from Blackhole Perturbations"
2011 08 03, D. Hilditch: "Hyperbolic gauge conditions and formulations of General Relativity"
2011 08 03, O. Sarbach: "Einstein's field equations as a Cauchy problem on compactified constant mean curvature hypersurfaces"
2011 08 04, K. Landsteiner: "The sound of strongly coupled field theories: quasinormal modes in Anti de Sitter space"
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2011 11 29, H. Hamm: "Integrability"
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2011 12 12, P. Cascini: "Some applications, open problems, etc..."
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The following codes indicate the association of visitors with particular programmes:

ABS-FU = Quantitativ Studies of Non Linear Wave Phenomena Follow-up Workshop
ACM = Advisory Committee Meeting
AGvs = Algebraic vs. Analytic Geometry
AS = Infinite monster groups
CAP = Guest of Prof. Cap
CGS = Non-commutative geometry, scattering theory and Witten index
DKM = Topological heterotic strings & (0,2) mirror symmetry
DKM2 = Memorial Conference Maximilian Kreuzer
ESS = Erwin Schrödinger Symposium 2011
FMC = Cartan Connections, Geometry of Homogenous Spaces, and Dynamics
GT = Completely integrable systems and applications
HBA = Dynamics of General Relativity: Numerical and Analytical Approaches
HLH-FU = Follow-up Workshop to the 2009 ESI Programme on "Selected topics in spectral theory"
JF = Junior Research Fellow
JKL = Rigorous quantum field theory in the LHC era
PC = Seminar on Mathematical relativity
SCH = Guest of Prof. Schmidt
SCHW = Guest of Prof. Schwermer
SF = Senior Research Fellows
SFS = Senior Research Fellow Share
SHS = Summer School in Mathematical Physics
SLE = Non linear water waves
THI = Guest of Prof. Thirring
VLS = Bialgebras in free probability
VS8 = 8th Vienna Central European Seminar on Particle Physics and Quantum Field Theory
YNG = Guest of Prof. Yngvason
ZEK = Combinatorics, number theory, and dynamical systems

Abdesselam Abdelmalek, University of Virginia, Charlottesville; 18.09.2011 - 24.09.2011, JKL;
Abe Takuro, Kyoto University; 28.11.2011 - 04.12.2011, AGVS;
Abenda Simonetta, University of Bologna; 03.07.2011 - 07.07.2011, GT;
Abert Miklos, Rény Institute, Budapest; 15.12.2011 - 15.12.2011, AS;
Adamczewski Boris, Institut Camille Jordan, Lyon; 10.10.2011 - 14.10.2011, ZEK;
Adams Allan, Massachusetts Institute of Technology, Cambridge; 20.06.2011 - 26.06.2011, DKM;
Aermark Lior Alexandra, Stockholm U.; 20.01.2011 - 26.01.2011, HLH-FU; 15.08.2011 - 24.08.2011, SHS;
Aguiar Marcelo, Texas A&M U., Coll. Stat.; 13.02.2011 - 27.02.2011, VLS; 03.03.2011 - 04.03.2011, VLS;
Aichelburg Peter C., Universität Wien; 24.01.2011 - 29.01.2011, ABS;
Aksteiner Steffen, ZARM, Univ. Bremen; 27.01.2011 - 30.01.2011, PC; 11.07.2011 - 17.07.2011, HBA;
Alazzawi Sabina, Universität Wien; 16.08.2011 - 24.08.2011, SHS; 20.09.2011 - 01.10.2011, JKL;
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Paul Severine, Université de Cergy-Pontoise; 15.08.2011 - 24.08.2011, SHS;
Paunescu Liviu, "Simion Stoilow" Institute, Bucharest; 13.12.2011 - 18.12.2011, AS;
Pelinovsky Dmitry, McMaster University, Hamilton; 09.06.2011 - 16.06.2011, SLE;

Pelloni Beatrice, University of Reading; 04.07.2011 - 05.07.2011, GT;
Penz Markus, Universität Innsbruck; 15.08.2011 - 24.08.2011, SHS;
Perlega Stefan, Universität Wien; 19.11.2011 - 13.12.2011, AGVS;
Petersen Kim, University of Copenhagen; 15.08.2011 - 24.08.2011, SHS;
Peterson Jesse, Vanderbilt University, Nashville; 13.12.2011 - 21.12.2011, AS;
Petrov Fedor, Steklov Institute, St. Petersburg; 12.11.2011 - 20.11.2011, ZEK;
Petrov Peter, Universidad de Sao Paulo; 18.11.2011 - 06.12.2011, AGVS;
Petz Dénes, Renyi Inst. of Math., Budapest; 31.01.2011 - 03.02.2011, VLS; 31.03.2011 - 21.04.2011, VLS;
Pfeiffer Harald, University of Toronto; 07.08.2011 - 15.08.2011, HBA;
Pfister Herbert, Universität Tübingen; 08.08.2011 - 12.08.2011, HBA;
Pizzo Alessandro, University of California at Davis; 21.09.2011 - 29.09.2011, JKL;
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Pocchiola Samuel, Université Paris XI, Orsay; 10.07.2011 - 16.07.2011, FMC;
Pohl Anke, ETH Zürich; 13.11.2011 - 19.11.2011, ZEK;
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Popescu Dorin Mihail, University of Bucharest; 18.11.2011 - 27.11.2011, AGVS;
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Pürrer Michael, Universität Wien; 04.07.2011 - 31.08.2011, HBA;
Pushnitski Alexander, King's Coll. London; 18.01. - 26.01.2011, HLH-FU; 02.02. - 05.02.2011, CGS;
Quigley Callum, University of Chicago; 20.06.2011 - 26.06.2011, DKM;
Quispel Reinout, La Trobe University, Melbourne; 06.07.2011 - 10.07.2011, GT;
Racher Gerhard, Universität Salzburg; 28.02.2011 - 27.03.2011, VLS;
Rácz István, RMKI, Budapest; 23.01.2011 - 29.01.2011, ABS-FU; 25.07.2011 - 31.07.2011, HBA;
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Ramirez Felipe A., University of Bristol; 09.10.2011 - 17.10.2011, ZEK;
Ramsey-Musolf Michael, University of Wisconsin-Madison; 24.11.2011 - 27.11.2011, VS8;
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Szybka Sebastian Jan, Jagiellonian University, Krakow; 26.01.2011 - 31.01.2011, PC;
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Tan Meng-Chwan, National University of Singapore; 19.06.2011 - 26.06.2011, DKM;
Tanabe Susumu, Galatasaray University; 25.11.2011 - 05.12.2011, AGVS;
Tasin Luca, Università degli studi di Trento; 05.12.2011 - 14.12.2011, AGVS;
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Vergnioux Roland, Université de Caen; 10.04.2011 - 15.04.2011, VLS;
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