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

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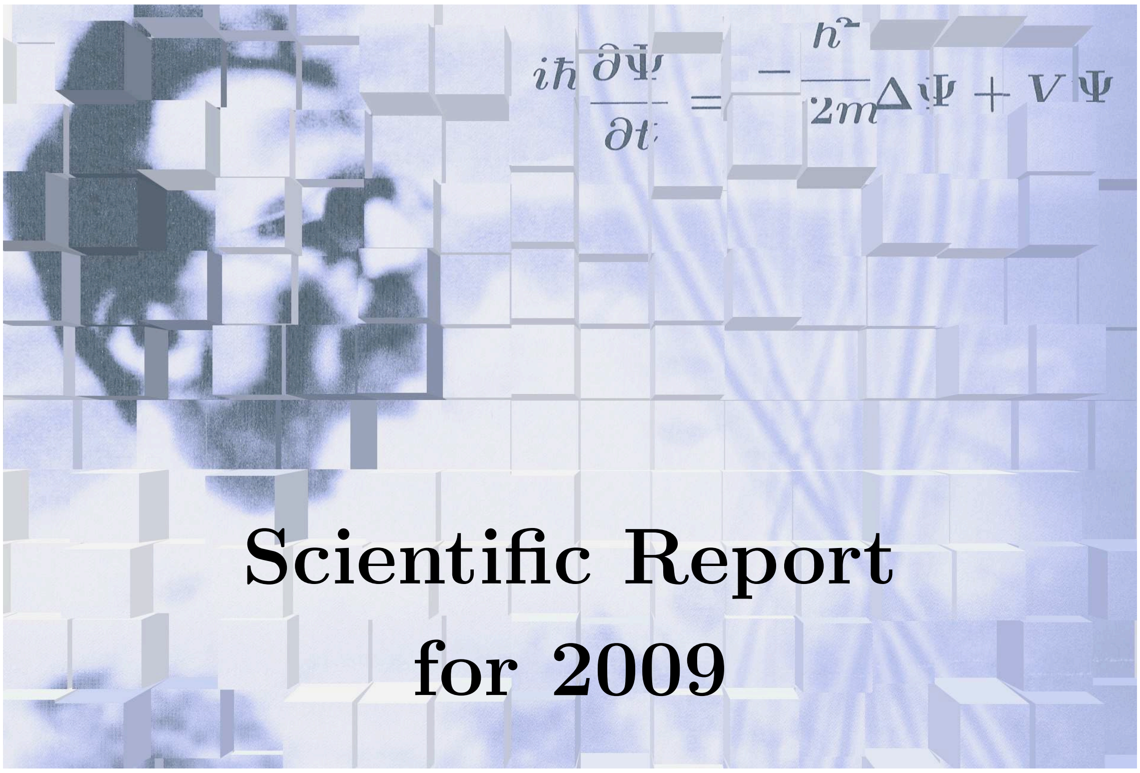

Scientific Report for 2009

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Contents

Preface

The major thematic programmes of the ESI in 2009 covered the following topics.

- *Representation Theory of Reductive Groups – Local and Global Aspects* (G. Henniart, G. Muić, J. Schwermer),
- *Number Theory and Physics* (A. Carey, H. Grosse, D. Kreimer, S. Paycha, S. Rosenberg, N. Yui),
- *Selected Topics in Spectral Theory* (B. Helffer, T. Hoffmann-Ostenhof, A. Laptev),
- *Large Cardinals and Descriptive Set Theory* (S. Friedman, M. Goldstern, R. Jensen, A. Kechris, W.H. Woodin),
- *Entanglement and Correlations in Many-Body Quantum Mechanics* (B. Nachtergaele, F. Verstraete, R. Werner),
- *The dbar-Neumann problem: Analysis, Geometry and Potential Theory* (F. Haslinger, B. Lamel, E. Straube).

Apart from these programmes (and the special workshops which were part of these programmes), a number of additional workshops and smaller meetings were organized at the ESI, including the following:

- *Mathematics at the Turn of the 20th Century: Explorations and Beyond* (D.D. Fenster, J. Schwermer),
- *Gravity in Three Dimensions* (H. Grosse, D. Grumiller, R. Jackiw, D. Vassilevich),
- *Recent Advances in Integrable Systems of Hydrodynamic Type* (A. Constantin, J. Escher),
- *Catalysis from First Principles* (J. Hafner, J. Norskov, M. Scheffler),
- *Classical and Quantum Aspects of Cosmology* (P.C. Aichelburg, H. Rumpf),
- *Quanta and Geometry* (A. Carey, J. Schwermer, J.Yngvason).

The *Senior Research Fellows Programme* of the ESI offered four lecture courses for graduate students and postdocs in 2009.

- *Spectral Triples in Noncommutative Geometry* by Raimar Wulkenhaar (Wilhelms-Universität Münster),
- *Spectral Inequalities and their Applications to Variational Problems and Evolution Equations* by Michael Loss (Georgia Institute of Technology, Atlanta),
- *Supergravity Theories* by Peter West (King's College, London)
- *L^2 Methods in Complex Analysis* by Jeff McNeal (Ohio State University, Columbus).

Under the *ESI Junior Research Fellows Programme* 27 postdocs and PhD students worked at the ESI during 2009 and contributed — as in previous years — significantly to the lively scientific atmosphere at the ESI.

Overall, the scientific activities of the ESI in 2009 were not quite up to the record levels of 2008 in terms of expenditure and visitor numbers, but nevertheless more than respectable. The Institute spent almost €650.000 on its scientific activities, with infrastructure costs just below €408.000. In 2009, 650 visiting mathematicians and physicists worked at the Institute.

The composition of the *International Scientific Advisory Committee* of the ESI changed in 2009 when Gerhard Huisken and Harald Grosse left the board, and Horst Knörrer (ETH Zürich) and Vincent Rivasseau (Orsay) joined it with effect from January 1, 2010. I would like to take this opportunity to thank the leaving members for their help and valuable advice over many years (in Harald Grosse's case 12!), and to welcome the new members warmly: I am very grateful to Horst Knörrer and Vincent Rivasseau for their willingness to support this Institute.

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

Klaus Schmidt April 2010
President

The ESI in 2009

Management of the Institute

Honorary President: Walter Thirring
President: Klaus Schmidt
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Administration: Isabella Miedl, Maria Windhager, Beatrix Wolf
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Budget and visitors: In 2009 the support of ESI from the Austrian Federal Ministry of Science and Research was €1.004.488,– (incl. €100.000,– for the Senior Research Fellows Programme and €214.488,– for the Junior Research Fellows Programme) and €29.000,– from the University of Vienna (incl. €22.000,– for the Senior Research Fellows Programme). The total spending on scientific activities in the year was €649.223,98 and on administration and infrastructure €407.869,59.

The number of scientists visiting the Erwin Schrödinger Institute in 2009 was 650, and the number of preprints was 139.

Scientific Reports

Main Research Programmes

Representation Theory of Reductive Groups - Local and Global Aspects

Organizers: G. Henniart (Paris), G. Muić (Zagreb), J. Schwermer (Vienna)

Dates: January 2 - February 28, 2009

Budget: ESI €65.415,55

Preprints contributed: [2119], [2120], [2121], [2132], [2133], [2137], [2147], [2148], [2151], [2153], [2156], [2196]

Report on the programme

In January and February 2009, the Erwin-Schrödinger Institute hosted a programme entitled *Representation Theory of Reductive Groups – Local and Global Aspects*, organized by Guy Henniart (U Paris XI), Goran Muić (U Zagreb) and Joachim Schwermer (U Vienna). This activity brought together leading experts in the theory of automorphic forms and representation theory as well as post-doctoral fellows from various countries. The main emphasis was put on some global aspects of the theory of automorphic representations as well as related local questions. That theory possesses a very strong structure given by the Langlands programme, in particular, the functoriality principle. This involves Galois or Weil group representations, the representation theory of local reductive groups, and questions regarding automorphic spectra.

One of the main goals in number theory is to understand the absolute Galois group $\mathcal{G}_k = Gal(k_{ac}/k)$ of a local or global field k. In the case of an algebraic number field, Artin attached to every finite dimensional representation $\rho : \mathcal{G}_k \to GL_n(\mathbb{C})$ its L-function $L(s, \rho)$, a complex analytic invariant. The study of the finite dimensional representation theory of $\mathcal{G}_k$ via these Artin L-functions represents one approach to understand the absolute Galois group in this case. Though these L-functions turned out to be fundamental in formulating and proving Artin's general reciprocity law, the crowning achievement of abelian class field theory, they served as well as essential ingredients in the search for a non-abelian class field theory. Parallel to this development, there are the L-functions of Hecke. Nowadays, these have to be viewed as special cases of L-functions attached to automorphic representations π of the general linear group $GL_n(\mathbb{A})$ over the ring of adeles of k.

It is one of the pillars of what is now known as the Langlands programme that there exists a correspondence between the n-dimensional representations of $\mathcal{G}_k$ and the automorphic representations of $GL_n(\mathbb{A})$ which preserves the corresponding L-functions. More precisely, given a reductive group G there is the complex dual group ${}^LG$, and the conjectures by Langlands predict natural correspondences between admissible homomorphisms of the Weil group W_k (a generalization of the absolute Galois group) into the dual group and automorphic representations of $G(\mathbb{A})$ and compatible local correspondences between admissible homomorphisms of

W_{k_v} into the dual group and admissible representations of $G(k_v)$ where k_v denotes the local field associated to a place v of the number field k. One can view this as an arithmetic parametrization of automorphic representations. If one views the passage of information from the automorphic side to the Galois (or L-group) side, this is a global or local non-abelian class field theory.

The principle of functoriality forms another pillar of the Langlands programme. This principle is associated to what is called an L -group homomorphism $\mu : {}^L H \to {}^L G$ between the L-groups attached to given reductive groups G and H. Whenever one has such a homomorphism, one should expect a strong relationship between automorphic representations of the two groups. This transfer of automorphic representations is encoded in the Langlands correspondence and mediated by an equality of Artin L-functions.

Since its first formulation in 1968, there has been significant progress made in understanding various facets of the Langlands programme. The main goal of the activity at the ESI was to stimulate further collaborative research by gathering specialists currently working in the realm of these questions.

More specifically, the main scientific themes of the activities within the programme were the following:

1. Automorphic Representations and L-functions. Cogdell worked on functoriality as a central question in the theory of automorphic forms. Global functoriality to GL_N for generic representations of quasisplit classical groups G has been established in many cases via an L-function method that combines the converse theorem for GL_N with the Langlands-Shahidi method for controlling the L-functions of classical groups. One of the crucial ingredients in this method is the use of a stability result for local factors to finesse the lack of the Local Langlands Conjecture at the ramified places of G. Cogdell explained how a general stability result allows to treat all quasi-split classical groups simultaneously.

Krishnamurthy worked on a new version of the converse theorem for $GL(2)$ over totally really fields, where the relevant L-functions are assumed to have nice analytic properties for all the unramified twists with substantially weaker conditions imposed on the remaining twists.

Jiang presented his recent results on periods of automorphic forms. These were motivated by the work of Harder-Langlands-Rapoport related to the Tate conjecture in the $GL(2)$ case. He extensively discussed Deligne's conjecture, and established, by using the work of Jacquet on the relative trace formula, special cases of Langlands functorial transfers. This led to a better understanding of special values (or poles) of certain L-functions.

Lapid investigated the question why the notion of a model is ubiquitous in the representation theory of reductive groups over local fields. Suppose that an irreducible representation is realized in two models. How can we compare the two realizations? He pursued this question in several examples, based on Rankin-Selberg type integrals, with a view towards applications in the global theory.

Raghuram pursued his work on Deligne's conjecture on the critical values of motivic L-functions while emphasizing the statement of this conjecture for symmetric power L-functions.

Kudla and Rapoport pursued work on their joint project on special cycles on Shimura varieties attached to groups of unitary similitudes of signature $(n-1,1)$. They succeeded in defining an elegant moduli problem of abelian varieties related to these Shimura varieties, and in defining the global analogues of the formal cycles from their previous work on them. They were also very far along in relating the intersection numbers of these special cycles to Fourier coefficients of Eisenstein series for the group $U(n,n)$, in the non-degenerate case. They are continuing to work out more examples.

Labesse worked on the transfer factors as defined by Langlands and Shelstad. It was his aim to obtain an alternative definition which is more suitable for explicit computations. He succeeded in getting a simple expression in some particular cases, in particular, for the transfer factors for endocopic groups of unitary groups when restricted to elements in the maximal torus which is a product of $U(1)$.

Moeglin continued her work on the normalization of the standard intertwining operators as they occur in the theory of Eisenstein series. She was able to show that the image of these operators is zero or irreducible. As a consequence she could describe residues of Eisenstein series attached to cuspidal automorphic forms on the Levi components of maximal parabolic subgroups. However, this work rests on the validity of Arthur's conjectures.

Grbac worked with Schwermer on the Eisenstein cohomology of arithmetic subgroups in classical groups, in particular, the symplectic group Sp_n of rank n split over the field of rational numbers. More precisely, they were interested in the contribution coming from (globally generic) cuspidal automorphic representations of the Levi factors of maximal proper parabolic subgroups. This circle of questions involves a detailed study of the analytic behaviour of the intertwining operators which naturally occur in the constant term of the Eisenstein series. In the case of the symplectic group they obtained a complete description of the contribution of relative rank one to the Eisenstein cohomology. A quite restricted set of conditions describes the possible existence of residual classes. A similar approach was taken by Gotsbacher and Grobner in the case of the split $SO(2n+1)$. Grobner and Grbac also discussed in the case Sp_2 over a totally real number field the contribution from the strata of maximal codimension, that is, the one originating with the minimal parabolic subgroups.

Harder continued during his stay his work on the arithmetic nature of the constant term of Eisenstein series of relative rank one which represent non-trivial cohomology classes for arithmetic groups. On one hand, his approach relies on his previous results regarding the construction of Eisenstein cohomology classes for arithmetic groups in this case, on the other hand, he has to investigate p-ordinary cohomology groups of arithmetic groups and an interpolating process of coefficient system. This latter work sheds new light on previous work of Hida and others. The case of arithmetic subgroups of the special linear group SL_3 was treated in some detail. Together with Mahnkopf, Harder began to construct certain p-adic families of cohomological automorphic forms. It is the final aim to provide a method for proving that in a certain sense ratios of special values of L-functions (which were previously considered in this context) are p-adic analytic functions.

Mahnkopf completed his construction of p-adic families of automorphic forms on $GL(2)$ as predicted by the Mazur-Gouvea conjecture. In the ordinary case he obtains the full conjecture, in the non-ordinary case his result is slightly weaker than the Mazur-Gouvea conjecture. This conjecture has been proven in the ordinary case by Hida, in general using completely different methods by Coleman. Mahnkopf's construction is based on a comparison of trace formulas, a technique which he adopted from the Langlands programme. Since he constructs families of automorphic forms he has to "compare infinitely many trace formulas". This comparison is also done modulo powers of p, i.e., he is partly working in characteristic $\neq 0$. Mahnkopf developed in his work a completely new approach by using the trace formula; it is open for generalizations to other reductive groups.

During the program, Blasius' principal research concerned the determination of the reductive group defined by the Zariski closure of an automorphic Galois representation. In particular, he speculated that, under the condition (in the characteristic zero case; there is no such condition in characteristic p) that the representations counted be cohomological, the asymptotic density, computed relative to the conductor, of those for which this group is maximal, is one. During the program he: (i) found most elements of a new strategy to prove the conjecture for $GL(N)$ in the function field case; (ii) worked on the proof for $GL(2)$, $GU(3)$ and $GSp(4)$ over a totally real field; (iii) worked on proofs of weaker (just positive density) results for all unitary groups using local methods, i.e. using the Harris-Taylor-Henniart local Langlands correspondence. For

(i) and (ii) one must proceed by direct computation of the densities of the non-full forms. This method cannot work at this point in general so various tricks especially using the fact that at a prime p, the local components at p of the forms in a suitable tower are distributed according to Plancherel measure. Proof of this latter fact in generality was a major topic of Blasius research and conversations. In fact, the general result was announced by Sug Woo Shin in Fall 2009 by a method very similar, using the trace formula, to that he envisioned.

Shahidi and Spallone worked on an ongoing project to relate the poles of intertwining operators to twisted endoscopy. Through the theory of intertwining operators for induced representations of a reductive group, one must come to terms with an integral over the unipotent radical N. A Levi component M acts on N by the adjoint action, and so one may decompose the integral according to the $\mathrm{Ad}(M)$-orbits. They treated cases in which M is the product $G \times H$ of two groups related by the norm correspondence of Kottwitz-Shelstad, and gave a Weyl integration-type formula for the integral over N. This is a functional which forces an interaction between the matched conjugacy classes of G and H. This is part of an ongoing project to relate the poles of these operators to twisted endoscopy.

In previous work Badulescu had established the global Jacquet-Langlands correspondence for inner forms of GL_N over an algebraic number field under the restriction that the local inner forms are split at the Archimedean places. In joint work with Renard, this condition could be removed. Consequently various new applications were derived by Badulescu.

2. Local Aspects of Automorphic Representations, unitarity and Arthur packets.

In the work of Burger, J.-S. Li and Sarnak on Ramanujan duals and the relation between the theory of automorphic forms on a group G and the one for a reductive subgroup H the notion of the automorphic dual of a real semisimple Lie group plays a decisive role. Clozel has extended this definition to groups over p-adic fields (in which case the automorphic dual is related to the asymptotics of Hecke eigenvalues). In two talks, M. Tadić explained his results on isolated unramified unitary representations in the automorphic duals of classical p-adic groups. He also discussed consequences of the Arthur conjecture, as formulated by L. Clozel in the unramified case, for the description of isolated representations in the unramified automorphic dual.

Let $G(F)$ be a classical group over a local non archimedean field F and let $M(F)$ be a maximal Levi subgroup of $G(F)$. Blondel continued her work, based on the strategy using types and covers, to compute the points of reducibility of representations of $G(F)$ parabolically induced from cuspidal representations of $M(F)$ and its connection with L-packets.

Savin, Hanzer, and Grbac discussed local and global aspects of the representation theory of metaplectic groups. They discussed the normalization of local intertwining operators via a method of Shahidi and how to find an appropriate notion of unramified representation in this framework. Matić, Muić and Hanzer were working on their approach via theta correspondence to the representation theory of p–adic metaplectic groups.

Hanzer was able to describe in some detail basic structural and representation–theoretical features of the two sheeted cover of the symplectic group over a p–adic field of characteristic zero. Then, following the work of Kudla and Muić, she could use the theta correspondence to find reducibility points for the generalized rank one case.

Jantzen discussed discrete series for p-adic $SO(2n)$ and the restrictions of representations of $O(2n)$. Shahidi introduced some general functionals by means of locally compact topological groups and their subgroups which generalize functionals that appear in the question of stability of root numbers and other related ones. As special cases these functionals give formal degrees, poles of intertwining operators and local coefficients, as well as some other arithmetic objects of interest.

Moy pursued research on distribution algebras of p–adic groups and Lie algebras.

Bushnell and Henniart explored a Clifford theory for the p–adic group $GL(n)$ and continued their study of the simple cuspidal representations of Gross-Reeder. Blondel, Henniart, and Stevens worked on explicating the Langlands correspondence for the symplectic group $Sp(4)$. Badulescu, Henniart and Mœglin discussed the archimedean problems raised by the theory of base change and automorphic induction.

Mœglin, Hanzer, Grbac, and Tadić discussed local Arthur packets for p-adic classical groups and their relation to questions of unitarizability and applications to residues of Eisenstein series. Mœglin and Muić were discussing how recent work of Arthur can be used to give some information on Hecke eigenvalues for cuspidal automorphic forms for split classical groups constructed by Muić.

Let G be a simply connected Chevalley group over a p–adic field, with the residue field of order q, corresponding to an irreducible simply laced root system. After illuminating talks by and discussions with Minguez and Secherre, Savin showed that the minimal representation V of G can be defined over $\mathbb{Q}$. He proved that the reduction of V modulo $l \neq p$ is minimal (in an appropriate sense) and is irreducible outside an explicit, finite set determined by q.

3. Types, l-adic, and p-adic representation theory.

Minguez and Secherre discussed the theory of smooth representations of $GL(m, D)$, with D a p-adic division algebra, and with coefficients in an algebraically closed field of characteristic l different from p. They presented partial results on the classification of irreducible representations by Zelevinsky–Tadić multisegments and the reduction modulo l of integral l-adic representations of such groups, having in mind a possible mod l Jacquet-Langlands correspondence.

Minguez investigated the possibility of having a local theta correspondence for l-modular representations. For the dual pair of type $(GL(n), GL(m))$ he found a new proof, valid if l is a prime number subject to a mild condition. This proof allows him to describe the correspondence in terms of Langlands parameters.

Schneider and Vignéras continued their work generalizing the work of Colmez on p-adic representations from $GL(2, \mathbb{Q}_p)$ to general p–adic reductive groups. In particular, Vignéras described a δ–functor from torsion representations of a Borel group of G to etale (φ, Γ)–modules over the Fontaine ring $\Lambda_F(\mathbb{Z}_p)$, using a non commutative microlocalisation, a generic Whittaker functional and compact induced representations. The question of finiteness remained open except for $GL(2, \mathbb{Q}_p)$.

Grosse-Klönne worked on problems in the same area of p–modular representations of p–adic groups. By now, the irreducible representations of $GL(2, \mathbb{Q}_p)$ on vector spaces over fields of characteristic p are well understood, but those of $GL(n, \mathbb{Q}_p)$, for $n > 2$, still remain, at present, an almost complete mystery. Motivated by a recent paper of Schneider and Vignéras he was working on constructing certain resolutions of such representations. This work was pursued in close contact with Schneider and Vignéras.

Henniart considered work of Gross and Reeder who have singled out some simple cuspidal representations for split reductive groups over a p–adic field F: they are induced from a simple character which is ramified, but minimally so. In the case of $GL(n)$, they are the cuspidal representations with Swan exponent 1. Determining what the corresponding representations of the Weil group are, is a non-trivial matter. If n is a power of p, they are primitive representations.

Stevens described the construction of supercuspidal representations of p-adic classical groups and completed the proof that these constructions give all supercuspidal representations of the underlying group.

Let F be a non-archimedean local field of residual characteristic p, let $n > 1$ be an integer. If D is a central division algebra over F of dimension n, the irreducible representations of $GL(n, F)$ and $GL(1, D)$ are related by the Jacquet-Langlands correspondence, which is formulated in terms of harmonic analysis. But both sides have an explicit description, and Bushnell presented an explicit Jacquet–Langlands correspondence in terms of these parametrizations.

Conclusion: The excellent facilities offered by the ESI, especially the possibility to concentrate on collaborative work and discussions, talks twice a week through the period, two held in the morning and the third early afternoon, and a light schedule during the workshop, enabled many collaborations to be continued, and new ones initiated during the period. It is the feeling of the organizers that this programme succeeded in presenting the state of the art of the field as well as set forth some new directions of research.

Invited scientists: Gordan Savin, Muthu Krishnamurthy, Vincent Secherre, Alberto Minguez, Harald Grobner, Marko Tadić, Dihua Jiang, Marie–France Vignéras, Dipendra Prasad, Erez Lapid, Günter Harder, Joachim Mahnkopf, Corinne Blondel, Marcela Hanzer, Takayuki Oda, Shaun Stevens, Mahdi Asgari, Takahiro Hayata, A. Raghuram, Neven Grbac, Ioan Badulescu, Jean–Pierre Labesse, Christoph Waldner, Chris Jantzen, Jim Cogdell, Michael Rapoport, Freydoon Shahidi, Allen Moy, Steven Spallone, Volker Heiermann, Samuel Patterson, Tobias Finis, Collin Bushnell, Stephen Kudla, Mirko Primc, Dražen Adamović, Peter Schneider, Colette Mœglin, Ivan Matić, Elmar Grosse-Kloenne, Don Blasius, Guido Kings, Jürgen Rohlfs, Gerald Gotsbacher

Number Theory and Physics

Organizers: A. Carey (Canberra), H. Grosse (Vienna), D. Kreimer (IHES), S. Paycha (Clermont-Ferrand), S. Rosenberg (Boston), N. Yui (Toronto)

Dates: March 2 - April 18, 2009

Budget: ESI €31.842,19

Report on the programme

The timetable for the program was as follows:

March 2 - 13 Instructional workshop

March 15 - 20 Number theory and physics conference

March 23 - April 6 Research in teams

April 7 - 10 Workshop

April 11 - 18 Research in teams

Instructional Lectures

The program had an intentional focus on expository talks throughout. The speakers for the instructional workshop were chosen to cover the two main themes of the meeting, namely Feynman integrals, perturbation theory and multi-zeta values on the one hand and statistical mechanical methods in arithmetic geometry on the other. Index theory also came up as a central topic in some of the lectures. Each lecture course comprised four lectures. Speakers and titles were as follows.

F. Brown (Ecole Normale Superieure, Paris): *Periods, polylogarithms and Feynman Integrals.*

D. Manchon (Clermont-Ferrand): *Connected Hopf algebras and renormalization.*

S. Paycha (Clermont-Ferrand): *Renormalised multiple sums and integrals with constraints: application to multiple zeta values and Feynman type integrals.*

A. Carey (ANU)/S. Rosenberg (Boston University): *Index Theorems in Riemannian and Noncommutative Geometry.*

K. Yeats (Simon Fraser): *Dyson-Schwinger equations.*

S. Ramadorai (Tata Institute): *Introduction to motives.*

M. Laca (University of Victoria): *Equilibrium and Symmetries from Number Theory.*

The audience of, on average 30 per course, contained many junior fellows and students. The feedback received by the organisers on the quality of the lectures was extremely positive. There was considerable interaction, many questions and informal discussions. As a result it was decided to produce a published version of some of the lectures. The authors who were approached to develop notes were Carey, Manchon, Paycha, Kreimer, Ramadorai, Plazas. In addition Dirk Kreimer gave a seminar in the Mathematics Department at the University of Vienna on his recent research in this field.

In the second week of the instructional program a further six research talks were also organised. This enabled the participants in the program interested in mathematical implications of perturbation theory in quantum field theory to hear about the latest developments in that area, especially on topics involving both number theory and quantum field theory at the threshold of which one expects to find deeper structures underlying quantum field theory. There was a lively and intense interaction between the members of this group throughout the initial two weeks, independently of their scientific background, with mathematicians talking to physicists or number theorists to geometers.. A number of recent and unpublished results were described in lectures and research collaborations amongst the participants were initiated. It is likely that many questions will be resolved in this area over the next year or two as a result of the interactions started at ESI.

Conference

The conference in the third week was devoted to both themes of the program. We will not reproduce the full program here. There were, on average, three talks per day leaving time for informal interactions. Junior Fellows were encouraged to speak and many took the opportunity thereby initiating discussions with more senior participants, which proved to be useful for the development of their own work.

In addition, for the first four weeks of the program one of the Senior Fellows present, Raimar Wulkenaar, gave a lecture series on noncommutative geometry. This added a valuable extra dimension to the program. The quality of the experience for junior researchers was also greatly enhanced by the large number (up to 10) of Junior Fellows and PhD students present during the first four weeks. This produced a lively group who were very involved with the lectures. In particular, Carolina Neira, Marie-Francoise Ouedraogo, Rongmin Lu, and Matthew Ingle to name a few, benefited greatly from the instructional workshop and discussions with the speakers that followed.

Second workshop

In weeks four and five there was a reduced level of formal activities. This enabled more informal interactions among the participants to occur and there were some very useful interactions on various research topics. These were facilitated by three of the organisers, Grosse, Carey and Rosenberg. In addition Vincent Rivasseau visited in week five and gave two 90 minute seminars on various aspects of quantum field theory. These lectures were very well attended and appreciated by both mathematicians and physicists, they came as a useful complement to the more specialised lectures delivered throughout the workshop.

The Workshop in week 6 suffered some unfortunate cancellations including Matilde Marcolli who had passport problems. This left a gap in the program in the area of statistical mechanical approaches to arithmetic geometry. Fortunately, Alan Carey and Joachim Cuntz were able to extend their presentations and to partially fill the gap. In addition Sylvie Paycha gave two detailed talks on residues and index theory which were of relevance to the interests of many participants. The full list of speakers for the workshop was A. Carey, J. Cuntz, S.Paycha, J. Lu, D. Manchon, Y. Neretin with presentations varying in length from one to two hours. We feel that interdisciplinary events such as this one, which stretch over several weeks, are indispensable for interactions across topics and fields to take place, from which can emerge new ideas leading to new developments in mathematics and theoretical physics. Since such interdisciplinary events are still rare, they are all the more valuable and appreciated.

Scientific Content

The lectures of Francis Brown dealt with the role of algebraic geometry in the calculation of Feynman integrals and the search for a counterexample to the notion that multi-zeta values were an inevitable outcome from such calculations (amongst other topics).

Alternative perspectives on this question from perturbation theory leading to non-perturbative statements, through Dyson-Schwinger equations, were also explored as a result of the lectures of Karen Yeats. A highlight here was the study of the structure of solutions of such quantum equations of motion in the case of quantum electrodynamics. For such gauge theories the existence of a parametrix has been proven by van Baalen, Kreimer, Uminsky and Yeats. Yeats reported on the bearing of these results to the triviality problem in QED and pointed out that asymptotic freedom follows beyond perturbation theory in QCD.

The study of the underlying integral kernels leads back to the questions studied in Francis Browns talk. Brown and Yeats indeed started a collaboration at this workshop, which led to a first recent joint paper (Spanning forest polynomials and the transcendental weight of Feynman graphs Authors: Francis Brown, Karen Yeats, arXiv:0910.5429v1).

The role of Hopf algebras in systematising the combinatorics of Feynman graphs was described by Manchon. Hopf algebras arising from shuffle products and their occurrence in other areas of mathematics were explained in his lectures. The intriguing occurrence of multizeta values in Feynman diagrams and the role of algebraic structures such as Hopf algebras in perturbative quantum field theory are a source for many questions which led to lively interactions among the researchers conversant in these matters and collaborations were initiated or continued.

The interaction between operator algebras, noncommutative geometry and number theory formed another theme. The participants were prepared for the material through lectures on Motives by Sujatha Ramadorai and on KMS states and Bost-Connes type systems by Marcelo Laca. A stimulating talk on the interaction of these ideas was given by Jorge Plazas. It was agreed that an expository article tying together motives and the methods of noncommutative geometry would be written by Plazas and Ramadorai together. The role of triangulated categories as a substitute for motivic cohomology was discussed and an explanation of the former notion was provided later in the program by Ryszard Nest. There again, much is yet to be said about the deep noncommutative and motivic structures underlying renormalization in quantum field theory, some of which are surprisingly similar to structures emerging from number theory.

Zeta residues arise in index theory both for pseudo-differential operators and through the local index formula in noncommutative geometry. Index theory is well known to play a role in gauge field theories via the study of anomalies. The latter are known to be described mathematically by the families index theorem and some of this theory was expounded by Steve Rosenberg in his lectures. It is an open problem to relate the zeta residues to the families index theorem and a conjectural framework for this was found by Alan Carey and Moulay Benameur and outlined in the ESI preprint nr. 2093. Zeta residues, traces and pseudo-differential operators formed the subject of Sylvie Paycha's talks. The role of cyclic cohomology and the local index formula in index theory was described by Alan Carey and a sketch of an application to Mumford curves was given. Operator algebras generalising those of Bost-Connes and inspired by number theoretic considerations were described in lectures by Joachim Cuntz. This bulk of talks related geometry and analysis to algebraic structures such as cyclic cohomology, but also Hopf algebras which arise in renormalization techniques. These talks showed the need to unveil deeper links expected between index theory and renormalization, in view of the role played in both fields by the noncommutativity.

The last week of the program overlapped with a meeting on three dimensional gravity. Program members were given some preliminary education in this topic by Vincent Rivasseau and hence were able to attend many of lectures in this final activity.

Invited Scientists: Vadim Alekseev, Peter Arndt, Gabriel Baditoiu, Christoph Bergbauer, Spencer Bloch, Louis Boutet de Monvel, David Broadhurst, Francis Brown, J. Alexander Cruz Morales, Joachim Cuntz, Herbert Gangl, Mathew Ingle, Satoshi Kondo, Marcelo Laca, Andrey Levin, Yoshiaki Maeda, Dominique Manchon, Ryszard Nest, Louise Nyssen, Marie Francoise Ouedraogo, Anna Paolucci, Jorge Plazas, Peter Presnajder, Sujatha Ramdorai, Vincent Rivasseau, Karl-Georg Schlesinger, Martin Schlichenmaier, Oliver Schnetz, Ali Shojaei-Fard, Armin Straub, Matt Szczesny, Raimar Wulkenhaar, Karen Yeats

Selected Topics in Spectral Theory

Organizers: B. Helffer (Orsay), T. Hoffmann-Ostenhof (Vienna), A. Laptev (London)

Dates: May 5 - July 25, 2009

Budget: ESI €53.252,77, Stockholm €9.000,–

Preprints contributed: [2140], [2154], [2167], [2182], [2183], [2184], [2185], [2186], [2187], [2192], [2193], [2194], [2197]

Report on the programme

Spectral theory of elliptic operators is at the heart of many problems related to functional analysis, mathematical physics and geometry, to name just a few. It is hence ubiquitous, but in most cases it is not the main goal. The aim of the programme was to concentrate on some of the unifying aspects of spectral theory, thereby including traditional topics but also some topics where some new developments are taking place or which have been not so well represented in recent workshops or other larger scientific activities. The focus was mostly on very concrete problem-oriented questions which arise simultaneously in independent applications. Of course the topics partly reflect the interests of the scientific organizers.

The main focus was on problems connected to the topics below:

1. *Schrödinger operators with special emphasis on magnetic fields.*
2. *Geometric spectral problems related to membranes and Riemannian manifolds.*
3. *Universal spectral inequalities.*
4. *Problems related to the pseudo-spectrum of non-selfadjoint operators.*

There were two workshops, one from May 11 to May 20 and the second one from July 6 to July 16. In the second workshop special emphasis was given to the item 4.

Michael Loss (who was at ESI as Senior Research Fellow) gave a special course on
Spectral inequalities and their application to variational problems and evaluation problems.
These lectures were closely related to the topic 3.

Most of the participants were at ESI during one or two of the conferences. But some, e.g. Benguria and Weidl, took part in the activity but could not participate in the workshops.

It might be appropriate to describe some of the topics and discussions which have taken place during the programme. In order to give a survey of the topics of the talks given grouped according to their content. Thereby only the name of the colleague who gave the lecture is mentioned and not her/his collaborators. The topics 1–4 are not disjoint and in many respects closely related.

1. Schrödinger operators

Spectral problems related to Schrödinger operators were a central topic in the programme. In particular Schrödinger operators with magnetic fields were discussed. Some of those questions are connected to the theory of superconductivity. Problems which are important for the analysis of the Ginzburg Landau equations require a deeper understanding of Schrödinger operators with magnetic fields. For instance the eigenvalue asymptotics for magnetic Schrödinger operators with Neumann boundary conditions are important. Here we just mention the talks on this family of problems by Fournais, Helffer, Kachmar, Kordyukov and Raymond.

Solovej presented a deep analysis of the behaviour of large atoms described by the Pauli operator with self-generated magnetic fields. Confining a particle with a magnetic field was discussed by Truc. Some uniqueness problems related to the Aharonov Bohm effect were presented by Terracini. Her talk is clearly also related to topic 2.

Periodic operators were considered by Parnovski, Shterenberg, Solomyak and Suslina.

Siedentop analyzed a new functional which is a promising variant of the traditional Hartree Fock model for atoms and molecules. Østergaard Sørensen presented the derivation of the Scott correction for large relativistic atoms and molecules. For the atomic case Siedentop considered a similar problem for atoms in the framework of a different model. Solovej investigated the thermodynamic limit of charged systems.

Other talks on Schrödinger operators were given by Safranov (characterization of operators without bound states) and by Holt on operators with random potential.

Østergaard Sørensen presented recent results on the analytic structure of eigenfunctions of atomic and molecular non-relativistic Schrödinger equations.

2. Geometric spectral problems

The spectral analysis related membranes and Riemannian manifolds split in a natural way in two parts. The low lying eigenvalues and the eigenvalue asymptotics. Of course there are some results which cover all eigenvalues.

There are "universal eigenvalue inequalities", mostly for the Laplacian, where the relation between different eigenvalues are considered independent of the geometry of the corresponding membrane. Harrell and Hermi gave talks on those problems. On Riemannian manifolds related inequalities were presented by El Soufi.

One of the fascinating aspects of the properties of low lying eigenvalues of membranes and Riemannian manifolds is the fact that there are close connections to classical isoperimetric problems. The classical result is the Faber-Krahn inequality, about 80 years old, which says that the lowest eigenvalue of a membrane (Dirichlet boundary conditions) is lowest for the membrane with the shape of a ball (or disk for the two dimensional case) with the same volume. A far reaching generalization including operators with drift has been presented by Nadirashvili. Van den Berg considered the minimization of the second eigenvalue of membranes with a perimeter constraint. Girouard investigated in his talk isoperimetric eigenvalue ratios for the Steklov problem.

In his talk Helffer introduced a non-linear analogue for eigenvalues (in relation with spectral minimal partitions) related to shape optimization. These results are in particular interesting since the case of equality for Courant's inequality is characterized. For the sphere a sharp result with an isoperimetric flavor was presented. Bonnaillie-Noel discussed numerical aspects spectral minimal partitions. Harrell gave a talk on the optimization of functionals on convex domains.

Freitas investigated the lowest eigenvalue for membranes with special shapes, also numerical aspects were presented. Benguria in his talk showed that there is an interesting connection between zeros of the Fourier transform of the characteristic function of a membrane and the Dirichlet eigenvalues.

The heat kernel of the Laplacian, respectively, its trace play an important role for spectral theory related to Weyl asymptotics, but not only. Banuelos and Friedlander considered recent developments related to the heat kernel.

Teschl considered in his talk the spectral theory for perturbed Krein Laplacians in non-smooth domains, a problem which is related to higher order operators. Weidl gave a lecture about spectral problems associated to elastic plates which also involve higher order operators.

There are many spectral quantities whose asymptotics is being investigated for large energies. This is a huge very active field related to the hot topic of quantum chaos. Jakobson and Polterovich presented recent results in this field. Mangoubi presented results on the local behaviour of nodes of eigenfunctions for large energies. One should remark that there is a common feeling that the two communities, one considering the high energy cases, often concentrating on the *generic case* the other investigating low lying eigenvalues and the corresponding eigenfunctions, should interact much more closely.

3. Universal spectral inequalities

Inequalities are the core of many topics in analysis, in particular in spectral analysis. Hence for many of the results mentioned above "*spectral inequalities*" play an important role. For instance the results on universal inequalities could be also be included in topics 3 and 2. Furthermore some of the isoperimetric results in topic 2 belongs partly also to topic 3.

The course given by Michael Loss was devoted to some very interesting inequalities with geometric background. Chapters about mass transportation and other recent developments, not so well known among mathematical physicists were also presented. Carlen gave a talk about entropy production in a classical model by Kac. Nazaret also spoke about entropy, diffusion and functional inequalities.

A striking new result about Hardy inequalities was presented by Avkhadiev. Not surprisingly Hardy inequalities were discussed a lot since quite a few participants are working in this topic. (Avkhadiev, Esteban, Frank, Hoffmann-Ostenhof, Laptev, Loss, ...).

Frank in his talk presented a new approach via inversion positivity to the sharp Hardy-Littlewood-Sobolev inequality. Bounds on the number of bound states for matrix valued potentials were described by Seiringer. Those inequalities are related to Lieb-Thirring inequalities and were subject to many discussions; quite a few colleagues are working in those, by now, classical subject of mathematical physics and functional analysis.

4. Non-selfadjoint operators

Recently there is growing interest in the spectrum of non-selfadjoint operators. The right spectral notion for such non-selfadjoint problems is the pseudo spectrum. Many new, barely understood phenomena arise; already for large matrices some interesting semiclassical phenomena show up.

An introductory lecture about such phenomena was given by Davies. Levitin in his talk described periodic non-selfadjoint problems with so-called PT symmetries. The pseudospectrum for non-selfadjoint pseudodifferential operators was investigated by Dencker in his lecture. Zworski spoke about Weyl asymptotics of eigenvalues which arise for the Toeplitz quantization of complex-valued functions on a $2n$ dimensional torus. Pravda-Starov discussed resolvent estimates for non-self adjoint operators and Hérau investigated subelliptic estimates for linearized kinetic equations. Lerner presented coherent states methods for hypoelliptic operators. Helffer showed how the pseudospectrum appears in evolution problems relative to superconductivity, when an electric field is present. Finally Laptev presented some new inequalities for complex eigenvalues.

At a first glance the topics in those talks sound quite different. But both the phenomena and the methods which are being developed unite those problems. Of course since the whole field is very young neither the notions nor the circle of problems have stabilized yet. New phenomena are to be expected.

Finally there were a few talks which do not fit into the topics above. But they are all clearly related to spectral theory. Colin de Verdière considered an inverse problem from seismology. Herbst gave a talk on analyticity properties of solutions to the Navier-Stokes equations. Kiselev presented nonlocal maximum principles for fluid dynamics. Kappeler spoke about Toda and KdV and Sobolev about Szegö limit theorems for operators with discontinuous symbols. Those colleagues belong firmly to the "spectral community" and their talks demonstrated also the broadness of spectral theory.

Of course many spectral problems have not or only barely been touched in this activity. For instance scattering theory, random Schrödinger operators or quantum graphs. But this was on purpose to keep the activity focussed.

Invited scientists: Alexandra Lior Aermark, Farit Avkhadiev, Rodrigo Banuelos, Rafael Benguria, Virginie Bonnaillie-Noel, Eric Carlen, Yves Colin-de-Verdière, Brian Davies, Nils Dencker, Ahmad El Soufi, Laszlo Erdoes, Maria Esteban, Søren Fournais, Rupert Frank, Pedro Freitas, Alexandre Girouard, Evans Harrell, Ira W. Herbst, Frédéric Hérau, Lotfi Hermi, Maria Hoffmann-Ostenhof, Jason Holt, Mette Iversen, Dmitri Jakobson, Ayman Kachmar, Thomas Kappeler, Alexander Kiselev, Yuri Kordyukov, Richard S. Laugesen, Nicolas Lerner, Jimena Royo Letelier, Michael Levitin, Michael Loss, Dan Mangoubi, Nikolai Nadirashvili, Bruno Nazaret, Thomas Østergaard Sørensen, Leonid Parnovski, Mikael Persson, Iosif Polterovich, Karel Pravda-Starov, Morten Grud Rasmussen, Nicolas Raymond, Oleg Safranov, Roman Shterenberg, Heinz Siedentop, Alexander Sobolev, Michael Solomyak, Jan Philip Solovej, Tatyana Suslina, Gerald Teschl, Jesper Tidblom, Francoise Truc, Michiel van den Berg, Timo Weidl, Maciej Zworski.

Large Cardinals and Descriptive Set Theory

Organizers: S. Friedman (Vienna), M. Goldstern (Vienna), R. Jensen (Berlin), A. Kechris (Los Angeles), W.H. Woodin (Berkeley)

Dates: June 14 - 27, 2009

Budget: ESI € 25.110,–

Report on the programme

The organisers of this 2-week workshop are thankful for the opportunity to invite most of the world's leading set-theorists to Vienna for a very enjoyable and successful meeting. The ESI provided excellent facilities and administrative help for our very large group (more than 125 participants!).

The first week of the meeting emphasized large cardinal theory and touched on nearly all aspects of this theory: forcing axioms, reflection principles, inner models, singular cardinal problems, embedding complexity, determinacy, absoluteness principles, partition theorems, ideals, as well as other topics. The second week addressed the rather different community of descriptive set-theorists and was concerned with abstract measure theory, Banach spaces, continua, Borel ideals, metric structures, analytic equivalence relations, structural Ramsey theory, dynamical systems, Borel complexity as well as aspects of ergodic theory. The majority of the participants stayed for the entire two weeks, providing for cross-fertilisation across two rather different communities of set-theorists.

Important new results were obtained as a result of the workshop; below is a list of some of them.

Kojman: Continuing the work of Spadaro on G_δ topologies, the following was proved using pcf theory: For every singular cardinal μ of cofinality κ the Noetherianity number of the G_δ topology obtained from the product topology on 2^μ is at most $\min\{(2^\kappa)^+, \mu^+\}$.

Larson: It is consistent that there are no medial limits.

Matrai: The nowhere dense ideal CalNwd and the asymptotic density ideal CalZ are Tukey-incomparable.

Cummings: 1. Suppose that $V \subseteq W$ are inner models of ZFC and that $(\aleph_{\omega+1})^V = \aleph_2^W$. Let $A \in V$ be an infinite subset of ω such that $tcf(\prod_{n\in A} \aleph_n/finite) = \aleph_{\omega+1}$ in V. Then *either* a) $cf^W(\aleph_n^V) = \omega$ for all but finitely many $n \in A$ OR b) There is in W a function $g \in \prod_{n\in A} \aleph_n^V$ which is not dominated by any function in $(\prod_{n\in A} \aleph_n)^V$. In particular W is not a proper forcing extension of V.
2. Consistently from a supercompact with a measurable above: There are models of set theory $V \subseteq W$ with the same cardinals and a cardinal κ which is inaccessible in V, and has cardinality ω_1 in W such that weak square with ω_1 clubs at each level (a variant due to Schimmerling of Jensen's classical weak square) fails in W. This contrasts with the situation when the cofinality of κ is changed to ω, where under mild extra conditions $\square_{\kappa,\omega}$ holds by work of Cummings-Schimmerling and Dzamonja-Shelah.

Ben Miller: There is a classical proof of the Harrington-Marker-Shelah Borel Dilworth theorem.

Aspero and Mota: There is a model where the continuum is large, Weak Club Guessing fails and Moore's mho principle holds. There is also a model in which the continuum is large, Weak Club Guessing holds and Moore's mho principle fails.

Farah: Building on work with Katsura, a class of noncommutative tori associated with graphs is introduced. As an application, a simple nuclear C*-algebra is constructed that has irreducible representations on both separable and nonseparable Hilbert spaces. This answered a 2002 question of Kishimoto–Ozawa–Sakai.

Yorioka: Todorcevic introduced fragments of $MA_{\aleph_1}$. One is K_2: Every ccc forcing notion has property K. We note that $MA_{\aleph_1}$ implies K_2, but the reverse implication is still open. The uniformization of a coloring of a ladder system by finite approximations has the rectangle refining property. Combining known results and this result, it is proved consistent that $K_2(rec)$ does not imply $MA_{\aleph_1}(rec)$.

Ikegami: Hugh Woodin observed that the axiom of real Blackwell determinacy ($Bl - AD_R$) implies the determinacy of all sets of reals in $L(R, R^{n\#})$ for any natural number n, where $R^{n\#}$ is the n-th iterate of the sharp operation starting from R. Combining work of Steel and Woodin, it is shown that the consistency of $Bl - AD_R$ is stronger than the existence of infinitely many Woodin cardinals with $V_\delta^{n\#}$, where δ is the supremum of the Woodin cardinals.

Ishiu, Yorioka: If T is a free Suslin tree, then $T \times T$ is proper yet T does not preserve the Suslinness of itself. This negatively answers the following question: If T is Suslin, P is a forcing notion and $P \times T$ is proper, then must P preserve the Suslinness of T?

Zdomskyy: It is consistent that there is no universal metrizable Menger space.

Saveliev: 1. In ZF without AC: No infinite well-ordered successor cardinal λ^+ can be covered by λ sets each of cardinality less than λ. Contrasting with many negative results (by Jech, Gitik, and others), this shows that the behaviour of cardinals without AC is not completely chaotic.
2. Well-known ZFC facts about quasi-disjoint families can be proved without AC. The only unclear case is when the cardinality of a given family is a successor cardinal of countable cofinality; in this case the result is slightly weaker than that proved by ZFC about singular cardinals.
3. A standard result says that any compact left topological semigroup has an idempotent; this allows one to use idempotent ultrafilters to obtain a lot of theorems in number theory, algebra,

and dynamics. This result can be extended to: Any compact left topological left semiring has a common, that is additive and multiplicative simultaneously, idempotent. There are similar results for more general universal algebras. As an application, this partially answers a question about the algebra of $\beta(N)$, the Stone–Cech compactification of the natural numbers.

Marciszewski, Plebanek: Rosenthal compacta are those compact spaces that can be represented as pointwise compact sets of Baire class one functions on some Polish space. It is known that every measure on a Rosenthal compactum is of countable Maharam type but it is an open problem if every such measure has some stronger property of being 'countably determined'. It is proved that the answer is yes in some important cases.

LaFlamme, Nguyen van The and Sauer: No countable dimensional vector space V over an infinite field F is weakly indivisible. In fact V can be divided into two parts so that neither part contains an affine line.

Soukup: Let $\mu \leq \kappa \leq \lambda$ be infinite cardinals.Then following are equivalent:
Every μ-almost disjoint family is essentially disjoint.
Every μ-almost disjoint family has disjoint refinement.
Every μ-almost disjoint family has transversal.

Friedman, Viale: It is consistent for BPFA to hold while some proper inner model with the correct ω_2 does not contain all reals. The proof uses collapses with finite conditions. This answers a question of Caicedo-Velickovic.

Invited Scientists: Alessandro Andretta, Arthur Apter, David Aspero, Joan Bagaria, Bohuslav Balcar, Tomek Bartoszynski, Tristan Bice, Joerg Brendle, Andrew Brooke-Taylor, Elizabeth Brown, Riccardo Camerlo, John Clemens, Samuel Coskey, James Cummings, Vincenzo Dimonte, Carlos Di Prisco, Natasha Dobrinen, Pandelis Dodos, Mirna Dzamonja, Inessa Epstein, Julia Erhard, Ilijas Farah, Qi Feng, Asaf Ferber, Valentin Ferenczi, Arthur Fischer, Vera Fischer, Jana Flaskova, Matt Foreman, David Fremlin, Shoshana Friedman, Sakae Fuchino, Su Gao, Moti Gitik, Victoria Gitman, Vassilis Grigoriadis, Andras Hajnal, Ajdin Halilovic, Joel Hamkins, Greg Hjorth, Peter Holy, Radek Honzik, Michael Hrusak, Daisuke Ikegami, Tetsuya Ishiu, Stephen Jackson, Tom Jech, Thomas Johnstone, Istvan Juhasz, Vladimir Kanovey, Jakob Kellner, Bernhard Koenig, Peter Koepke, Menachem Kojman, John Krueger, Aleksandra Kwiatkowska, Claude Leflamme, Giorgio Laguzzi, Paul Larson, Benedikt Loewe, Alain Louveau, Robert Lubarsky, Menachem Magidor, Adrian Mathias, Tamas Matrai, Julien Melleray, Heike Mildenberger, Ben Miller, Hiroaki Minami, Bill Mitchell, Don Monk, Miguel Angel Mota, Luca Motto, Lionel Nguyen, Janusz Pawlikowski, Luis Pereira, Grzegorz Plebanek, Assaf Rinot, Christian Rosendal, Marcin Sabok, Grigor Sargsyan, Norbert Sauer, Denis Saveliev, Ernest Schimmerling, Ralf Schindler, Philipp Schlicht, Farmer Schlutzenberg, Dima Sinapova, Slawomir Solecki, Lajos Soukup, Otmar Spinas, Jiri Spurny, Mack Stanley, John Steel, Simon Thomas, Katherine Thompson, Stevo Todorcevic, Asger Toernquist, Victor Torres, Todor Tsankov, Boban Velickovic, Matteo Viale, Philip Welch, Wolfgang Wohofsky, Teruyuki Yorioka, Jindra Zapletal, Lyobomyr Zdomskyy, Miroslav Zeleny, Martin Zeman

Entanglement and Correlations in Many-Body Quantum Mechanics

Organizers: B. Nachtergaele (Davis), F. Verstraete (Vienna), R. Werner (Hannover)

Dates: August 10 - October 17

Budget: ESI €54.593,40

Report on the programme

The long term programme "Entanglement and correlations in many-body quantum mechanics" was held at the ESI from August 10 till October 17 2009. The bulk of the activity happened during the first month when approximately 70 people attended the ESI.

The programme was kicked off by a workshop with the title "Quantum Computation and Quantum Spin Systems". Thereafter, the long term programme started with a focus on entanglement and correlations in many-body quantum mechanics.

The number of talks was deliberately held very low during the whole period, such that there would be ample time for making use of the fantastic facilities and especially the long blackboards at the institute.

The practical aspects of organizing the workshop were mostly taken over by the enthusiastic staff at the ESI, and both the organizers and the participants are full of praise for the very efficient and professional way things were handled: we would like to thank the staff of the ESI wholeheartedly.

The workshop resulted in quite a large number of new collaborations and papers. All in all, we are very glad that we got the opportunity to organize this workshop and programme at the ESI, and would like to thank the ESI for their very generous support and help.

Abstracts

We present here the list of the official talks held during the workshop in alphabetical order, together with their abstracts when available. This list can also be found online under *http://qit.univie.ac.at/conference/schedule.html* where most of the presentations can be downloaded and in cases where abstracts are missing we refer below to these presentations. Besides the official talks, there were many informal talks and discussions held within smaller groups.

Dorit Aharonov (Hebrew University, Tel Aviv): *Is there a quantum PCP theorem?*

Itai Arad (University of California at Berkeley): *Quantum gap amplification and the detectability lemma.*

Fernando Brandao (Imperial College, London): *The complexity of poly-gapped Hamiltonians. Extending Valiant-Vazirani theorem to the probabilistic and quantum settings.*
Abstract: Valiant-Vazirani showed in 1985 that solving NP with the promise that yes instances have only one witness is powerful enough to solve the entire NP class (under randomized reductions). We are interested in extending this result to the quantum setting. We prove extensions to the classes MA and QCMA. Our results have implications on the complexity of approximating the ground state energy of a quantum local Hamiltonian with a unique ground state and an inverse polynomial spectral gap. We show that the estimation, to within polynomial accuracy, of the ground state energy of poly-gapped 1-D local Hamiltonians is QCMA-hard, under randomized reductions. This is in strong contrast to the case of constant gapped 1-D Hamiltonians, which is in NP. Moreover, it shows that unless QCMA can be reduced to NP by randomized reductions, there is no classical description of the ground state of every poly-gapped local Hamiltonian, which allows the calculation of expectation values efficiently. Finally, we discuss a few obstacles towards establishing an analogous result to the class QMA. This is joint work with Dorit Aharonov, Michael Ben-Or and Or Sattath.

Sergey Beavyi (IBM Research): *Perturbative expansions based on the Schrieffer-Wolf transformation.*
Abstract: It is widely believed that perturbative series for quantum field theory and many-body physics do not converge but are to be viewed as asymptotic series, meaning that their lowest-order terms provide a good approximation to the quantity of interest while inclusion of higher-order terms may actually give a worse result. We provide a quantitative version of this conjecture that can be rigorously proved for a large class of quantum spin models in which the unperturbed (free) Hamiltonian describes noninteracting spins (qudits) while the perturbation is a k-local Hamiltonian. Our proof relies on the Schrieffer-Wolff transformation of many-body physics that allows one to derive effective low-energy Hamiltonian preserving locality features of the original Hamiltonian. This is a joint work with David DiVincenzo and Daniel Loss.

Paul Fendley (Virginia University): *Duality and Topological Order.*

Daniel Gottesman (Perimeter Institute): *Computational Complexity of Translationally Invariant Systems.*
Abstract: In general, finding the ground state energy of a spin system (quantum or classical) is a computationally hard problem. For a quantum system, this is true even in one dimension. Of course, there are also systems, which are easy to simulate; some can even be solved analytically. What are the key distinguishing properties between the hard systems and the easy systems- One might expect that symmetry should play a role. However, we show that even with a great deal of symmetry - translational invariance spin systems remain hard to solve in general. This is joint work with Sandy Irani.

Stephen Jordan (Caltech): *QMA-Complete Problems for Stochastic Hamiltonians and Markov Matrices.*
Abstract: Finding the lowest eigenvalue of a 3-local symmetric stochastic matrix is QMA-complete. Finding the highest energy of a stochastic Hamiltonian is QMA-complete and adiabatic quantum computation in the highest energy state and certain other excited states of a stochastic Hamiltonian is universal. These results give a new QMA-complete problem arising in the classical setting of Markov chains, and new adiabatically universal Hamiltonians, which arise in many physical systems.

Lluis Masanes Meruelo (ICFO, Barcelona): *An area law for the entropy of low-energy states.*
Abstract: It is often observed in the ground state of spatially extended quantum system with local interactions that the entropy of a large region is proportional to its surface area. In some cases, this area law is corrected with a logarithm factor. This contrasts with the fact that in almost all states of the Hilbert space, the entropy of a region is proportional to its volume. In this talk it is shown that low-energy states have (at most) an area law with the logarithmic correction, provided two conditions hold: (i) the state has sufficient decay of correlations, (ii) the number of eigenstates with vanishing energy density is not exponential in the volume. These two conditions are satisfied by many relevant systems. The central idea of the argument is that energy fluctuations inside a region can be observed by measuring the exterior and superficial shell of the region.

Daniel Nagaj (IPSAS, Bratislava): *Local Hamiltonians in Quantum Computation.*
Abstract: Knowing the ground state properties of some quantum spin systems could help us solve interesting computational problems. This approach produced many results about the complexity of the Local Hamiltonian and Quantum k?SAT problems. On the other hand, local, time independent (even translational invariant) Hamiltonians can have another interesting property. Their Schrödinger time evolution of simple initial states can be a universal tool for quantum computation. I will review the underlying principles and techniques under the proofs of both of these approaches, present new results about the BQP universality of Quantum 3-SAT (and qubit-qutrit Quantum 2-SAT) Hamiltonians and discuss the connections to Adiabatic Quantum Computing.

Zohar Nussinov (Washington University): *Duality mappings via bond algebras, their applications to quantum spin systems, and implications for quantum information.*
Abstract: We show how exact dualities as well as duality relations that appear only in a sector of certain theories (emergent dualities) can be systematically derived. Our method relies on the use of bond algebras wherein the algebraic relations between all terms in the Hamiltonian are examined. Self-dualities are further characterized as unitary transformations with peculiar properties. This method enables us to solve exactly several quantum spin systems in high dimensions. Particular applications of this method allow the investigation of systems with topological quantum order by relating these systems to simpler well-known systems for which bounds on the possible memory time can be attained (thermal fragility).

Tobias Osborne (Royal Holloway, London): *When is a Quantum Spin System Frustrated?*
Abstract: Quantum spin systems arise in many applications in condensed matter physics, e.g. as models for low-temperature magnetism. Quantum spin systems also naturally arise in quantum information theory: there exists a family of 1D quantum spin systems completely capturing the complexity of quantum computation. Such systems are called QMA complete, meaning that they are easy to specify, and if you could decide if the system is frustrated or not (up to some threshold) then you could easily simulate the outcome of any quantum computation (and much more besides!). In this talk, I aim to partially answer the question in the title. I will describe a general procedure to decide when a quantum spin system is frustrated or not. While this method is not generally efficient it will allow the study of generic 1D quantum spin systems with d-dimensional spins: I will show how to argue that, generically, a quantum spin system whose pair wise interactions have rank less than $d^2/4$ (as matrices) are always frustration-free (or, satisfiable)

David Poulin (Universite de Sherbrooke): *Markov Entropy Approximation Scheme.*
Abstract: I will present a new numerical method to estimate thermal properties of quantum spin systems. The method makes use of strong sub-additivity to upper bound the systems entropy by a sum local terms. This Markov approximation provides a rigorous lower bound to the systems free energy. Estimating the free energy then reduces to a convex optimization problem with linear constraints that can be easily handled numerically. Finally, I will present preliminary results obtained for the two dimensional anti-ferromagnetic Heisenberg model.

Robert Sims (Arizona University): *Lieb-Robinson bounds for an-harmonic lattice systems.*
Abstract: Over the past few years, the locality estimates first proven in 1972 by Lieb and Robinson, in the context of quantum spin systems, have been revisited and demonstrated to have a variety of interesting applications. The topic of this talk is a version of the Lieb-Robinson type bounds, which are applicable to oscillator systems. In particular, we prove that for a suitable class of perturbations of the harmonic system, one can derive explicit estimates on the group velocity v. This result demonstrates that the support of a time-t evolved local observable remains essentially localized in a ball of radius vt.

Shivaji Sondhi (Princeton University): *Random Quantum Satisfiability.*
Abstract: Alongside the effort underway to build quantum computers, it is important to better understand which classes of problems they will find easy and which others even they will find intractable. We study random ensembles of the QMA1-complete quantum satisfiability (QSAT) problem introduced by Bravyi. QSAT appropriately generalizes the NP-complete classical satisfiability (SAT) problem. We show that, as the density of clauses/projectors is varied, the ensembles exhibit quantum phase transitions between phases that are satisfiable and unsatisfiable. Remarkably, almost all instances of QSAT for any hypergraph exhibit the same dimension of the satisfying manifold. This establishes the QSAT decision problem as equivalent to a, potentially new, graph theoretic problem and that the hardest typical instances are likely to be localized in a bounded range of clause density. (Work with C. Laumann, R. Moessner and A. Scardicchio)

Guifre Vidal Bonafont (University of Queensland): *Entanglement renormalization in two spatial dimensions: frustrated antiferromagnets and interacting fermions.*
Abstract: The multi-scale entanglement renormalization ansatz (MERA) has been recently shown to be a useful tool to study quantum many-body systems that are beyond the reach of quantum Monte Carlo techniques. On a two-dimensional lattice, both frustrated antiferromagnets (G. Evenbly and G. Vidal, arXiv: 0904.3383) and interacting fermions (P. Corboz, G. Evenbly, F. Verstraete and G. Vidal, arXiv:0904.4151) can be efficiently simulated provided that the amount of ground state entanglement remains sufficiently small. I will review these results and explain how to treat bosonic and fermionic systems on the same footing within the MERA formalism.

Short description of notable results obtained during the workshop:

A breakthrough result that resulted from discussions and work during the programme has been reported in the paper *Topological quantum order: stability under local perturbations* by Sergey Bravyi, Matthew Hastings, Spyridon Michalakis (arXiv: 1001.0344). It was a long-term open problem whether the topological quantum order present in the quantum spin Hamiltonians named after Kitaev and Levin and Wen was robust under local perturbations of the Hamiltonian. The paper settled this issue by using ideas inspired by Lieb-Robinson bounds and renormalization flow equations.

A second important result derived during the workshop is a result in the context of quantum computational complexity. A famous theorem in combinatorics is the so-called Lovasz local lemma, which characterizes conditions such that certain objects exist for relevant classes of optimization problems. Andris Ambainis, Julia Kempe and Or Sattath generalized this famous lemma to the quantum case at the ESI, and wrote a paper called *A Quantum Lovasz Local Lemma* (arXiv:911.1696). Besides a technical tour de force, they had to overcome conceptual barriers of how to formulate the problem in the language of quantum logic. This paper was presented at the ACM Symposium on Theory of Computing (STOC'10), the most prestigious conference in computer science, and also as an invited talk at the premier conference of quantum computation (QIP 2010).

A third result that received quite some attention has been the formulation of a quantum version of the Metropolis algorithm. In the manuscript *Quantum Metropolis Sampling* (arXiv:0911.3635, K. Temme, T.J. Osborne, K.G. Vollbrecht, D. Poulin, F. Verstraete), a long-standing open problem in the field of quantum computation was solved, i.e. how can a quantum computer be used to simulate static properties of strongly correlated quantum many-body systems. In the manuscript, the authors show how the Metropolis algorithm for simulating classical interacting systems can be generalized to the quantum case. This proves that a quantum computer can be used as a universal quantum simulator, and also that the sign problem can be circumvented on a quantum computer. A major portion of this work was done during the programme.

Invited Scientists: Antonio Acin, Miguel Aguado, Dorit Aharonov, Andris Ambainis, Itai Arad, Assa Auerbach, Joseph E. Avron, Thomas Barthel, Gergely Barcza, Bela Bauer, Fernando Brandao, Sergey Bravyi, Horracio Casini, Pochung Chen, Xie Chen, Stefano Chesi, Marcus Cramer, Andrew Daley, Nilanjana Datta, Stefan Depenbrock, Wolfgang Dür, Jens Eisert, Viktor Eisler, Hans Gerd Evertz, Paul Fendley, Michael Fleischhauer, Jürg Fröhlich, Florian Froewis, Sibasish Ghosh, David Gosset, Daniel Gottesman, David Gross, Shi-Jian Gu, Jutho Haegeman, Aram Harrow, Fumio Hiai, Sandy Irani, Liang Jiang, Maria Jivulescu, Stephan P. Jordan, Julia Kempe, Robert König, Vladimir Korepin, Chris Laumann, Ors Legeza, Elliott Lieb, Netanel Lindner, Andrew Lutomirski, Alexander Mai, Lluis Masanes, Peng Mei, Spyridon Michalakis, Roderich Moessner, Milan Mosonyi, Dominik Muth, Daniel Nagaj, Volckmar Nebendahl, Reinhard Noack, Zohar Nussinov, Yoshiko Ogata, Enrique Ortega, Tobias Osborne, Ingo Peschel, Denes Petz, David Poulin, Tomaz Prosen, Angie Quarry, Oded Regev, Beat Roethlisberger, Mary Beth Ruskai, Or Sattath, Antonello Scardicchio, Ulrich Schollwöck, Voker Scholz, Norbert Schuch, Robert Seiringer, Robert Sims, Kirill Shtengel, Shivaji Sondhi, Shannon Starr, Barbara Terhal, Meagan Thompson, Guifre Vidal Bonafont, Michael Wolf, Magdalena Zych.

The $\bar{\partial}$-Neumann Problem: Analysis, Geometry, and Potential Theory

Organizers: F. Haslinger (Vienna), B. Lamel (Vienna), E. Straube (Texas)

Dates: October 27 - December 23, 2009

Budget: ESI € 47.139,91, START € 22.000,–, Amadee and Acciones Integradas € 2.000,–

Preprints contributed: [2158], [2202], [2204], [2208], [2209], [2210], [2211], [2212]

Report on the programme

The program brought together scientists working in Several Complex Variables and closely related areas in order to discuss current research in the field. The main theme, the $\bar{\partial}$–Neumann problem, has its roots in the 1950s, and ties together the analysis of several complex variables with analysis, geometry, and potential theory. Many modern techniques in Several Complex Variables have their roots in the analysis of the $\bar{\partial}$–Neumann problem, and the problem itself has opened up whole new fields during the development of tools for its analysis. Thus, as anticipated, the theme worked very well in providing a common ground to the ongoing current research which was discussed and presented during the program. In particular, there were discussions and talks about:

- Different aspects of regularity in the $\bar{\partial}$–Neumann problem
- Aspects of the $\Box_b$ and $\bar{\partial}_b$ operator
- Convexity notions in Several Complex Variables
- The worm as a (counter)example
- Connections with multiplier ideal sheaves and algebraic geometry
- Boundary geometry of domains in $\mathbb{C}^n$
- Potential theoretic aspects of the theory of plurisubharmonic functions
- Holomorphic dynamics and the $\bar{\partial}$-equation on currents

Associated with the program was a Senior Fellow lecture series on '$\mathcal{L}^2$-methods in complex analysis' by Jeff McNeal. There were also five participants who held Junior Fellowships. The organizers made a special effort to accommodate early stage researchers, in addition to the junior fellows. Because many leading and prominent figures from the field of Several Complex Variables attended, the program provided a forum for these young researchers to attract attention to their work. At the same time, they were exposed to important current developments. The organizers are convinced that this kind of interaction will have an important impact on the careers of the junior researchers attending the program.

We now discuss various aspects of the program in more detail. Of course, all topics overlap with the overarching theme of the program, the (regularity theory of) the $\overline{\partial}$-Neumann problem. But there is considerable interaction among the other sections as well. For example, properties of the boundary operators are intimately connected to the geometry of the boundary, which in turn is related to various notions of convexity, and so forth.

Senior Fellow lecture series on '$\mathcal{L}^2$-methods in complex analysis'

Jeff McNeal gave a series of inspiring lectures on the twisted $\overline{\partial}$ -estimates, where he showed how to develop the fundamental results on the $\overline{\partial}$ problem from suitably chosen weights in the Kohn-Morrey formula. In each of his lectures there were about 20 permanent participants, mainly younger post-docs and the ESI junior fellows. Many aspects in a series of preprints by Anne-Katrin Herbig, Janhavi Joshi, Yunus Zeytuncu, Klaus Gansberger and Friedrich Haslinger were directly influenced by McNeal's excellent presentation. We regret very much that, due to personal reasons, he was not able to finish his lecture series in the planned way but hope he will have occasion to complete the series at a later time.

Participating Junior Fellows

The organizers very much appreciate the generous allocation of Junior Fellowships to the program by the Schrödinger Institute's scientific administration. There were a total of six fellowships awarded; one awardee declined shortly before the start of the program. The five participating Fellows were:

- Slawomir Dinew, Jagiellonian University
- Zywomir Dinew, Jagiellonian University
- Lukasz Kosinsky, Jagiellonian University
- Jean Ruppenthal, Universität Wuppertal
- Jean-Charles Sunye, Université de Rouen

Regularity in the $\bar{\partial}$–Neumann problem

Regularity in the $\bar{\partial}$–Neumann problem has been one of the driving forces of the theory. This problem is the prototype of an elliptic PDE which is not coercive at the boundary, and the special flavor of the theory of several complex variables can often be explained by trying to understand how much boundary structure is needed in order to gain regularity.

Of special importance in regularity questions for the $\bar{\partial}$–Neumann problem are the notions of *subellipticity* and *compactness*.

Subellipticity has been classified in terms of a boundary invariant by Catlin: the $\bar{\partial}$–Neumann problem is subelliptic on a smoothly bounded pseudoconvex domain $\Omega \subset\subset \mathbb{C}^n$ if and only if $b\Omega$ is of finite type (the order of contact of $b\Omega$ with complex varieties is bounded). One of the reasons for the renewed interest in subellipticity is its connection to multiplier ideals (which will be discussed later); the talk by Kohn touched this subject, other related talks were given by D'Angelo and Derridj (who discussed subellipticity for a system of vector fields with characteristics).

There are still aspects of subellipticity in which there is ongoing interest. In particular, the finite type condition gives rise to a family of plurisubharmonic functions which have large Hessians near the boundary, and the order of blowup is related to the subelliptic gain. The talk of Straube introduced some of the open problems in that area.

A weaker notion than subellipticity is compactness, which is also classically known to imply regularity in the $\bar{\partial}$–Neumann problem by results of Nirenberg and Kohn. There are potential theoretic conditions (conditions (P) of Catlin and $(\tilde{P})$ of McNeal) which imply compactness and can be seen as limiting conditions to the blowup of Hessians in the subelliptic case. However, even though there has been considerable interest in the question, currently no geometric characterization of these potential theoretic conditions exists, nor do we know whether (P) (or $(\tilde{P})$) actually characterize compactness. Several talks touched this important issue.

For regularity questions, another important approach is the vector field method introduced by Boas and Straube. The talk by Harrington featured a new mixture of condition (P) and the vector field condition. This new condition is also not yet understood in terms of its precise geometric or potential theoretic content.

There is considerable activity concerning regularity questions when the domains are 'rough', i.e. only Lipschitz. The talks of Ehsani and Lieb reported on their results concerning the $\overline{\partial}$-Neumann operator and the Bergman projection, respectively, in this context.

The exchange of new techniques and ideas for regularity questions has been very lively and we expect that new developments in this field have been sparked by the program.

Boundary operators

The non-coerciveness of the $\bar{\partial}$–operator and the geometric and potential theoretic conditions needed for regularity are mirrored in the associated boundary complex of the $\bar{\partial}_b$-operator. The analysis of the boundary operators is very delicate, but there have been important advances over the last couple of years. Ongoing current research has been reported by Boggess and Raich. Several discussions around the occurring convexity notions showed that they are not well understood, and we expect to see some research into that question. In addition, Charpentier reported on research related to the Szeg kernel, as did Hirachi.

Convexity notions

Convexity is the most important geometric notion employed in Several Complex Variables. The biholomorphically invariant notion of pseudoconvexity characterizes domains of holomorphy in several complex variables, and the complex analytic analogue of a convex function is a plurisubharmonic function. However, not every pseudoconvex domain can be realized (even locally) as a convex domain, and not every pseudoconvex domain can be defined by plurisubharmonic functions. This important difference to real convexity gives rise to a hierarchy of convexity conditions. Understanding the interplay of these geometric notions as well as how they can be applied analytically is an ongoing research theme, on which many of the given talks touched. Convexity conditions are also intimately related to the behaviour of invariant metrics, which was another aspect on which there were a number of talks and discussions.

The worm domain

The worm domain, originally introduced by Diederich and Fornæss as an example of a smooth bounded paeudoconvex domain whose closure does not admit a Stein neighborhood basis, turned out to be one of the most versatile counterexamples in Several Complex Variables. As such, many of the speakers introduced one or the other variant of the worm domain and used it as a (counter) example for their particular problem. Interesting ongoing research into the Bergman kernel on one such variant of the worm has been reported by Krantz. Also, Şahutoğlu reported on current joint research with Barrett on higher-dimensional variants of the worm.

Multiplier ideal sheaves

Analogues of the multiplier ideal sheaves introduced by Kohn to study subellipticity in the $\bar{\partial}$–Neumann problem have found widespread use in algebraic geometry, and analytic methods coming from several complex variables had an important impact on the development of this field. The talks by Siu introduced many questions which arise from such problems in algebraic geometry and there is considerable interest in these problems; we hope that the exchange provided by the program will further improve the ties between Several Complex Variables and Algebraic Geometry. Popovici's talk on deformation limits of compact Kähler manifolds also fits into this intersection.

Boundary geometry

The geometric and potential theoretic conditions already discussed give rise to important problems in understanding the biholomorphically invariant boundary geometry of domains. Many talks were given which reported on ongoing research in that area. Moreover, the program helped to shape some of the geometric questions which come from analysis, and will lead to further research into questions like how one can find geometric descriptions for the existence of plurisubharmonic defining functions (as noted above, there is a whole hierarchy of convexity notions which still need to be understood). Also, during the program new research collaborations in this area were formed, and new projects have been started.

Potential Theory

We have already noted the importance of potential theoretic conditions above, and potential theoretic ideas permeated the whole program. But in addition, a number of topics were discussed that belong to 'potential theory proper'. These topics included the notion of finely plurisubharmonic functions (a notion of plurisubharmonicity arising from consideration of the fine topology, rather than the Euclidean topology), connections to Voiculescu's entropy, the Monge-Ampère equation (on Hermitian manifolds), and applications of classical potential theory to holomorphic partial differential equations.

Holomorphic dynamics

In holomorphic dynamics, a basic tool is the analysis of the $\bar{\partial}$–equation on currents, which in itself is an important extension of the classical theory (which is also of use in algebraic geometry). Topics discussed included dynamics of holomorphic automorphisms, normal forms for holomorphic dynamical systems, and laminations (from a dynamical systems point of view).

Invited Scientists: Mats Andersson, Luca Baracco, Youssef Barkatou, Shif Berhanu, Lea Blanc-Centi, Zbigniew Blocki, Thomas Bloom, Harold Boas, Al Boggess, Antonio Bove, Josep Burgues, Mehmet Celik, Philippe Charpentier, Zeljko Cuckovic, John D'Angelo, Maklouf Derridj, Klas Diederich, Slawomir Dinew, Zywomir Dinew, Tien-Cuoung Dinh, Roman Dwilewicz, Armen Edigarian, Dariush Ehsani, Vladimir Ejov, Miroslav Englis, John-Erik Fornaess, Franc Forstneric, Gabor Francsics, Siqi Fu, Klaus Gansberger, Josip Globevnik, Nihat Gogus, Chong-Kyu Han, Philip Harrington, Bernard Helffer, Anne-Katrin Herbig, Kengo Hirachi, Howard Jacobowitz, Marek Jarnicki, Michal Jasiczak, Janhavi Joshi, Robert Juhlin, Tran Vu Khanh, Dima Khavinson, Sung Yeon Kim, J.J. Kohn, Martin Kolar, Slavomir Kolodziej, Lukasz Kosinski, Steven Krantz, Loredana Lanzani, Christine Laurent, Lina Lee, Jürgen Leiterer, Ingo Lieb, Erik Lundberg, Xavier Massaneda, Emmanuel Mazzilli, Ben McLaughlin, Jeff McNeal, Francine Meylan, Joachim Michel, Nordine Mir, Bela Nagy, Andreea Nicoara, Nikolai Nikolov, Stephanie Nivoche, Takeo Ohsawa, Jong-Do Park, Marco Peloso, Joe Perez, Peter Pflug, Dan Popovici, Andrew Raich, R. Michael Range, Sivaguru Ravisankar, Jean-Pierre Rosay, Jean Ruppenthal, Sonmez Şahutoğlu, Giuseppe della Sala, Gerd Schmalz, Mahmood Shabankah, Nikolay Shcherbina, Nessim Sibony, Yum-Tong Siu, Laurent Stolovitch, Jean-Charles Sunye, David Tartakoff, Giuseppe Tomassini, Alex Tumanov, Brett Wick, Jan Wiegerinck, Hassan Youssfi, Yuan Yuan, Dmitri Zaitsev, Guiseppe Zampieri, Crystal Zeager, Yunus Zeytuncu, Wlodzimierz Zwonek.

Workshops Organized Outside the Main Programmes

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

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

Dates: January 16 - 23, 2009

Budget: Budget contribution by the ESI €1.000,–

Report on the programme

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

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

Mathematics at the Turn of the 20th Century

Organizers: D. Fenster (Richmond), J. Schwermer (Vienna)

Dates: January 2 - 12, 2009

Budget: ESI €11.803,92

Report on the programme

This workshop provided a focused venue to investigate the history of mathematics during a particularly active time in the discipline, that is, at the turn of the 20th century. This workshop grew out of and, in some sense, served as an afterward for a conference held at the Mathematisches Forschungsinstitut Oberwolfach in May, 2008. To explore this vibrant period, the organizers brought together mathematicians, historians of mathematics and historians of science to consider ideas and offer insights from different perspectives. With this wide range of scholars in attendance, speakers had to give careful thought to the presentation of their work. This extra effort not only yielded a sterling set of talks but also inspired scholars to rethink their own work.

The restricted time period revealed an almost unexpected richness in the history of mathematics as conference participants discussed points of connection between the people, places and ideas from fields as seemingly diverse as class field theory, mathematical physics and algebraic geometry, among others. In her talk, for example, Martina Schneider of Leipzig presented the conceptual development of band spectra with group theoretic methods. In so doing, she unraveled the process involved in the emergence of the new field of quantum chemistry. Her careful analysis of Wolfgang Paulis willingness to apply newly developed ideas in group theory to his own work, in contrast to other physicists who were less inclined to make use of this new approach, called attention to the hesitancy and delicateness of new ideas finding their way into various research programs. Schneiders talk underscored the critical importance of the study of the history of mathematics for what it has to teach current scholars, in this case, about the importance of considering new ideas before rejecting them entirely. Taking up the topic of number theory, Catherine Goldstein of Paris used the work of Jacques Herbrand to explore efforts to revitalize French mathematics in the 1920s by looking to the contributions of German mathematicians.

Her analysis of class field theory, a topic of what is often referred to as modern mathematics, suggested a revision of thoughts on this larger topic. Thus Goldsteins talk provided a perfect case study of Moritz Epples ambitious discussion of modern mathematics. Epple discussed this broad topic by comparing the two seminal texts on this topic, Herbert Mehrtens *Moderne Sprache Mathematik* and Jeremy Grays very recent *Platos Ghost: The Modernist Transformation of Mathematics*, and extending their ideas.

In commemoration of Hermann Minkowskis death on January 12, 1909, two talks at the workshop illuminated Minkowskis work in mathematics and physics. Scott Walter of Nancy retraced the history of Minkowskis approach to physics. The seminars Minkowski co-directed with Hilbert, including the 1905 seminar on electron theory, established a niche for sophisticated mathematical investigations of problems in mechanics and physics, in contrast to the phenomenological approach of Woldemar Voigt, on the one hand, and the emphasis on concrete applications championed by Carl Runge and Felix Klein, on the other hand. Minkowski's approach was further clarified by an examination of his lecture notes on heat radiation, which shed new light on his discovery of spacetime. Minkowski's peculiar understanding of the role of mathematics in understanding physical phenomena seemed to lead to a troubled reception of spacetime theory, and the challenge this theory represented for theoretical physicists in Germany and abroad. In his talk on Minkowski as number-theorist, Samuel Patterson of Göttingen traced Minkowskis early career from his days as a student at the university of Königsberg where he had studied together with David Hilbert under the guidance of F. Lindemann and A. Hurwitz to his time as a young Privatdozent at the University of Bonn. Patterson emphasized the two different themes that were central to Minkowskis research in the following years. He was inclined to deepen his interest in physics and he vigorously pursued his geometric approach to the arithmetic theory of quadratic forms and its relationship to questions in number theory. Finally, Patterson discussed the major contributions of Minkowski to various arithmetic research areas such as Diophantine approximation, the theory of algebraic numbers and the local-global principle.

Taken together, the depth and breadth of the topics, as illustrated by the examples cited above, reflect not only the various influences on the development of mathematics but also the myriad of ways to approach the subject itself. Organizing the workshop around a time frame, rather than a mathematical discipline, brought together a unique combination of scholars and allowed for a vibrant discussion across fields and national borders. The conference placed an especial emphasis on the presence of and contributions by young scholars. Their fresh perspective fostered a vibrant spirit during the meeting. The organizers would like to thank the ESI for their generous support of this workshop.

Invited scientists: June Barrow-Green, Birgit Bergmann, Frederic Brechenmacher, Bill Cable, Renaud Chorlay, Moritz Epple, Sebastian Gauthier, Catherine Goldstein, Jeremy J. Gray, Nico Hauser, Juliette Leloup, Samuel Patterson, Jim Ritter, Laura Rodriguez, Dan Rudary, Norbert Schappacher, Bjoern Schirmeier, Martina Schneider, Erhard Scholz, Reinhard Siegmund-Schultze, Scott Walter.

Gravity in Three Dimensions

Organizer: D. Grumiller (Vienna), R. Jackiw (MIT), D. Vassilevich, H. Grosse (Vienna)

Dates: April 14 - 24, 2009

Budget: ESI € 27.043,94

Preprints contributed: [2139], [2145], [2149], [2150], [2188]

Report on the programme

The aim of the workshop “Gravity in three dimensions” at the ESI was twofold. It brought together leading experts and pioneers of gravity in three dimensions, and it provided a series of introductory and advanced lectures for the benefit of local students and faculty members. The workshop was attended by experts in the fields of gravity, black hole physics, conformal field theory (CFT), AdS/CFT correspondence, Chern-Simons theory, integrable models and string theory. We had four talks each day which still allowed plenty of time for discussions and collaborations during the two weeks of the workshop.

Gravity in three dimensions has a very special status in theoretical and mathematical physics. Because the Weyl tensor is absent in three dimensions and since pure Einstein gravity exhibits no physical bulk degrees of freedom considerable simplifications arise that allow to tackle deep questions about quantum gravity and the theory of black holes. Despite of these simplifications models of three dimensional gravity are not trivial and may exhibit massive graviton excitations discovered by Deser, Jackiw and Templeton and black hole solutions found by Bañados, Teitelboim and Zanelli (BTZ). A recurring theme and useful tool is the reformulation of various three-dimensional gravity models as linear combinations of Chern-Simons terms.

In 2007 Witten argued that three-dimensional gravity with a negative cosmological constant may lead to a consistent theory of quantum gravity via the AdS/CFT correspondence, and his considerations – particularly his conjecture that for a certain tuning the dual CFT is the monster theory of Frenkel, Lepowsky, and Meurman – engendered a lot of further research in theoretical and mathematical physics. In 2008 several groups (Anninos, Li, Maloney, Padi, Song and Strominger; Carlip, Deser, Waldron and Wise; Grumiller, Jackiw and Johansson; Lowe; Sachs and Solodukhin; Giribet, Kleban and Porrati; Compere and Detournay; de Haro; Henneaux, Martinez and Troncoso; and others) considered topologically massive gravity of Deser, Jackiw and Templeton extended by a negative cosmological constant and revealed several intriguing features of this model, some of which are still poorly understood. In particular, for a certain tuning of the cosmological constant the bulk graviton excitations degenerate with the boundary graviton excitations and the boundary CFT may become chiral, as conjectured by Li, Song and Strominger. On the other hand, Grumiller and Johansson found that this degeneration may lead to logarithmic excitations and conjectured the boundary CFT to be a logarithmic CFT. These conjectures are mutually exclusive and thus provided the basis of interesting discussions, which led to a vigorous study by a number of groups in 2008/2009 (including a sizable fraction of the invitees), both from the gravitational and the CFT perspective. Shortly before the workshop Bergshoeff, Hohm and Townsend proposed a novel theory of gravity in three dimensions – so-called "new massive gravity" – that shows some resemblance (but also crucial differences) to topologically massive gravity.

Main topics of the program

- AdS/CFT and Kerr/CFT correspondence
- Chiral gravity, new massive gravity and supergravity
- Classical and quantum BTZ black hole and three dimensional quantum gravity
- Conformal properties
- Extremal CFTs and logarithmic CFTs
- Warped AdS, asymptotic symmetries and central charges

In the following we briefly describe some of main subjects of the program.

AdS/CFT and Kerr/CFT correspondence. The AdS/CFT correspondence (or gauge/gravity duality) is particularly rich for gravity in three dimensions, since the dual CFT allows for local conformal symmetry. Several talks exploited this correspondence, some of them with the intention to get insight into quantum gravity. Hartman and Song discussed a novel version of that correspondence with possible applications to extremal Kerr black holes.

Chiral gravity, new massive gravity and supergravity. Strominger presented his model of "chiral gravity" and discussed recent evidence in favor of the chiral CFT conjecture, concurrent with findings presented by Carlip. Becker introduced supersymmetry in that model in her talk on "chiral supergravity". Hohm presented "new massive gravity".

Classical and quantum BTZ black hole and three dimensional quantum gravity. The BTZ black hole was the subject of several talks. For example, Sachs discussed quasi-normal modes and black hole stability in topologically massive gravity. In many of the quantum gravity presentations the BTZ black hole featured prominently, for instance in Yin's talk on the 3D gravity partition function.

Conformal properties. The Weyl tensor vanishes in dimensions four or higher if and only if spacetime is conformally flat. In three dimensions the Cotton tensor takes the role of the Weyl tensor. Conformal properties and the relations between Weyl tensor in four dimension and Cotton tensor in three dimensions were addressed in several talks, for instance the talk by Jackiw who discussed the dimensional reduction of the Weyl tensor to three dimensions.

Extremal CFTs and logarithmic CFTs. CFTs were addressed in many of the talks. Particularly, Gaberdiel discussed difficulties with the construction of extremal CFTs for arbitrary values of central charges. The logarithmic and chiral CFT conjectures were the subject not only of talks, but also of a discussion session and many private discussions.

Warped AdS, asymptotic symmetries and central charges. Warped AdS spaces are the negatively curved analog of Hopf fibrated spheres. They are not asymptotically AdS and present several challenges in their theoretical description and for an establishment of a gauge/gravity duality. Several talks were devoted to this subject, including a pedagogic introduction by Henneaux.

Summary. The ESI workshop on gravity in three dimensions brought together most of the leading scientists in the field. The introductory lectures were very helpful for local students and faculty members. Nearly all of the seminar talks contained very recent results and engendered a lot of fruitful discussions. Several collaborations commenced during the workshop and led in the meantime to novel results on chiral (super-)gravity, warped AdS spacetimes, new massive gravity and logarithmic CFTs.

Invited scientists: Dionysios Anninos, Maximo Bañados, Melanie Becker, Eric Bergshoeff, Steve Carlip, Geoffrey Compere, Sebastian de Haro, Stephane Detournay, Dimitry Fursaev, Matthias Gaberdiel, Jack Gegenberg, Gaston Giribet, Monica-Maria Guica, Thomas Hartman, Marc Henneaux, Olaf Hohm, Alfredo Iorio, Victor Isakov, Niklas Johansson, Dietmar Klemm, Gabor Kunstatter, David Lowe, Alex Maloney, Christian Martinez, Rene Meyer, Catherine Meusburger, Jeanette Nelson, Massimo Porrati, Ivo Sachs, Bernd Schroers, Adam Schwimmer, Wei Song, Andy Strominger, Stefan Theisen, Ricardo Troncoso, Andrew Waldron, Xi Yin, Jorge Zanelli.

Catalysis from First Principles

Organizers: J. Hafner (Vienna), J. Norskov (Denmark), M. Scheffler (Berlin)

Date: May 25 - 28, 2009

Budget: ESI € 4.000,–

Report on the programme

The Working Group "Catalysis and Surface Science" of the Ψ_k-Network organizes a biannual series devoted to the discussion of recent progress and methodological advances in first-principles methods applied to catalysis, co-organized by Jürgen Hafner (Universität Wien), Jens Norskøv (Technical University of Denmark) and Matthias Scheffler (Fritz-Haber Institute of the Max-Planck Gesellschaft. The sixth workshop in this series was held from May 25 to May 28, 2009 at the Erwin Schrdinger Institute (ESI) for Mathematical Physics in Wien. The workshop was sponsored by the Ψ_k-Network, the ESI, the Center for Computational Materials Science and the institutions of the organizers.

Topical sessions were devoted to the discussion of
(A) *Recent progress in density functional theory of solids - and beyond* (invited speakers J.P. Perdew, B. Lundqvist. S. Grimme, G. Kresse, M. Fuchs)
(B) *Ab-initio calculations of free-energy barriers and reaction rates* (C. Dellago, M. Parrinello, H. Metiu, T. Bucko, T. Bligaard)
(C) *Materials design* (D. Morgan, F. Studt)
(D) *Catalysis by metals and metal-support interactions* (G. Pacchioni, S. Piccinin, R. Grybos, P. Raybaud, A. Michaelides, A. Gross)
(E) *Electrocatalysis* (M. Koper, J. Rossmeisl, S. Sugino)
(F) *Acid-based catalysis in zeolites and related materials* (J. Sauer, L. Benco, R. Catlow, S. Bordiga)
(G) *Catalysis by oxides* (R. Schlögl, F. Mittendorfer, C. Noguera, J. van Bokhoven, K. Reuter)
Sessions A and B described recent progress in the methodology. Session A concentrated on the development of improved exchange-correlation functionals and on attempts to push the level of theory beyond density-functional methods, with the aim to achieve an improved description of weak "non-bonding" interactions (van-der-Waals forces, hydrogen bonds) by accounting for dynamical many-electron correlations. The presentations in Session B described current attempts to push the theoretical description of chemical reactions beyond the level of harmonic transition-state theory, using concepts such as Monte-Carlo based transition-path sampling and free-energy integrations using molecular dynamics simulations based on collective reaction-path variables. The contributions to Sessions C to G described the state of the art in key areas of catalysis research, from catalysis on metals and oxides over electrocatalysis to nanoporous systems (zeolites and metal-organmic frameworks) and included a discussion of multi-scale simulation methods designed to bridge the gaps in the time-, pressure- and temperature-gaps between atomistic simulations and real-world experiments.

Invited scientists: Lubomir Benco, Thomas Bligaard, Silvia Bordiga, Marten Börketun, Davide Branduardi, Tomáš Bučko, Javier Carrasco, Richard Catlow, Christoph Dellago, Cesare Fanchini, Thomas Franz, Martin Fuchs, Luca Ghiringhelli, Florian Göltl, Stefan Grimme, Axel Groß, Robert Grybos, Wei Guo, Heine Hansen, Judith Harl, Tao Jiang, Adam Kuejna, Jesper Kleis, Marc Koper, Georg Kresse, Yueh-Lin Lee, Sergey Levchenko, Bengt Lundqvist, Matteo Maestri, Sebastian Matera, Horia Metiu, Angelos Michaelides, Florian Mittendorfer, Dane Morgan, Claudine Noguera, Gianfranco Pacchioni, John Perdew, Simone Piccinin, Pascal Raybaud, Xinguo Ren, Karsten Reuter, Jan Rossmeisl, Souheil Saadi, Joachim Sauer, Robert Schlögl, Nicola Seriani, Aloysius Soon, Felix Studt, Osamu Sugino, Anja Toftelund, Loredana Valenzano, Jeroen van Bokhoven, Jenny Vitillo, Shengguang Wang.

Architecture and Evolution of Genetic Systems

Organizers: R. Bürger (Vienna), A.G. Jones (College Station), S.J. Arnold (Corvallis)

Dates: July 20 - 25, 2009

Budget: WWTF € 15.029,69

Report on the programme

This workshop was dedicated to recent developments in the study of models of the evolution of multivariate traits, in which the genes affect several correlated traits. To understand such models properly, the underlying genetic architecture has to be explored. In addition, the genetic architecture itself is a result of the evolution caused by selection on the traits. Therefore, the study of the genetic architecture is a central issue in evolutionary biology which is being investigated by numerous research groups using diverse approaches. The aim of this workshop was to bring together representatives from some of these groups so that they can share information, discuss objectives, and perhaps establish collaborations.

Two interrelated topics featured most prominently in the talks and the extensive discussions: (i) the evolution of the so-called G-matrix and (ii) epistasis and the evolution of gene networks.

(i) The G-matrix is a matrix of additive genetic variances and covariances. It describes to what extent traits have genetic variation and whether or not different traits are genetically correlated with one another. Genetic variance is necessary for traits to evolve, so the G-matrix tells us whether or not traits will evolve. Traits that are genetically correlated with one another don't evolve independently, so the G-matrix also describes whether or not groups of traits will evolve together. To understand the evolution of a phenotype made up of several traits, one needs to understand the G-matrix. Genetically, it is determined by the pattern of pleiotropic mutation at the loci contributing to the traits and their correlations. However, also selection and random genetic drift play important roles in shaping it, and epistasis and other features of the genetic system or the population biology may lead to serious complications. Therefore, the G-matrix is a result of evolution, guided and constrained by complex mechanisms. Understanding this evolution is an important topic of current empirical and theoretical research and was one of the central issues in this workshop.

(ii) Most traits, or trait complexes, are determined by a multitude of interacting genes. Phenotypic properties of gene networks, such as the G-matrix, are only one important facet of research. For many purposes, it is essential to understand the interaction among the genes (epistasis) and the dynamics of gene networks in more detail. In particular, it is essential to elucidate the evolutionary consequences of epistasis and the principles guiding the evolution of gene networks. This has become an extremely active research area and was the second main focus in this workshop.

Speakers: Steve Arnold (Corvallis): Simulation studies of G-matrix evolution and stability

Nick Barton (Klosterneuburg): What limits the size of the functional genome?

Bill Cresko (Eugene): Integrating quantitative genetics and molecular population genomics

Anton Crombach (Utrecht): Signatures of evolvability on the genome and network level

Jeremy Draghi (Philadelphia): Evolvability and its evolution: Moving from concepts toward experiments

Thomas Hansen (Oslo): Epistasis and the evolution of genetic architecture

Joachim Hermisson (Vienna): Evolution of genetic architecture in a simple epistatic model

David Houle (Tallahassee): Causes of G-matrix stability

Adam Jones (College Station): The evolution of the M-matrix and G-matrix in a two-trait model of epistasis

Christoph Krall (Vienna): Theoretical predictions for the G-matrix under mutation-selection balance

Steve Proulx (Santa Barbara): Do population structure and environmental variability have the strongest effect on the evolution of gene interactions?

Kirsten ten Tusscher (Oslo): Genetic architecture in polymorphism and sympatric speciation

Günter Wagner (New Haven): Genetic variation and selection on pleiotropy: rQTL and rQTL selection

Michael Whitlock (Vancouver): The dominance of new mutations

Invited Scientists: Nick Barton, William Cresko, Anton Crombach, Jeremy Draghi, Thomas Hansen, Joachim Hermisson, David Houle, Christoph Krall, Steve Proulx, Kirsten ten Tusscher, Günter Wagner, Michael Whitlock

Classical and Quantum Aspects of Cosmology

Organizers: P.C. Aichelburg (Vienna), H. Rumpf (Vienna)

Dates: September 28 - October 2, 2009

Budget: ESI €1.400,–

Report on the programme

The intensive course "Classical and Quantum Aspects of Cosmology" was organized by the Central European Joint Programme of Doctoral Studies in Theoretical Physics (Particle Physics, Gravity and Cosmology), the University of Vienna, and ESI. It was held from September 28 to October 2, 2009 and consisted of a total of 20 hours of lectures and exercise sessions. The first part of the lectures was given by Peter C. Aichelburg and consisted of a general introduction to the standard model of relativistic cosmology. The second part, delivered by Helmut Rumpf, presented an introduction to cosmological inflation with special emphasis on the quantum generation of cosmological perturbations.

About 20 students attended the course, with about half of them from the University of Vienna, the other half from Universities in Croatia, Slovakia and the Czech Republic.

Invited Scientists: Stephen Broda, Jorge Luis Cayao Diaz, Silvije Domazet, Markus Fedra, Nicolai Friis, Gressel Hedda, Albert Huber, Jörg Kammerhofer, Denis Kochan, Georg Kopsky, Emilia Kubalova, Elisa de Llano, Patrick Ludl, Anja Marunović, Peter Maták, Nataliya Paltseva, Martin Polactzk, Patrizia Schmidt, Matej Srovran, Nathalie Tassotti, Josip Turkalj.

Quanta and Geometry

Organizers: A. Carey (Canberra), J. Schwermer (Vienna), J. Yngvason (Vienna)

Dates: October 8 - 9, 2009

Budget: ESI €2.404,34

Report on the programme

The workshop was inspired by the research work of Harald Grosse and touched on many of the topics that he had contributed to in a substantial fashion over his career.

The workshop started with a Schrödinger Lecture delivered by Vincent Rivasseau. His talk described the situation in the mathematical study of renormalization, beginning with ordinary quantum field theory and ending with a discussion of the more recent examples of noncommutative field theories and of group field theories. Thanks to a recent breakthrough by Harald Grosse and Raimar Wulkenhaar renormalisable field theories on noncommutative space-times have been shown to exist. For these models renormalization becomes an essential tool to blend together in a new way classical geometry and the quantum theory.

Index theory and supersymmetry have been intertwined for several decades. Fritz Gesztesy spoke about some recent developments in which the Fredholm index, spectral flow and the spectral shift function of quantum scattering theory are seen to be interleaved. Recent work of Pushnitski was generalised (based on joint work Y. Latushkin, K. A. Makarov, F. Sukochev, and Y. Tomilov).

Hopf algebra methods are playing a role in the understanding of quantum field theory and Dorothea Bahns spoke about some recent research in which the Shuffle Hopf algebra is important for in describing combinatorial aspects of physical theories.

Krzysztof Gawedzki explained an aspect of the application of gerbes to quantum field theory. Gerbes are geometric structures behind higher degree holonomies contributing to Feynman amplitudes of topologically non-trivial higher-form fields. He discussed the example of Wess-Zumino- Witten and Chern-Simons theories with non-simply-connected Lie groups whose subtle relations are clarified with the use of gerbes.

Gauge field theories play a central role in our description of nature. But In spite of such successes, gauge theories continue to present major computational and conceptual challenges to modern theoretical physics. About ten years ago, the first examples of so-called gauge-string dualities have opened an entirely new approach to these issues. Volker Schomerus explained how to reinterpret quantities in (planar) gauge field theories through a string theoretic generalization of harmonic analysis. Within this framework, some selected recent developments were reviewed.

Invited Scientists: Peter Christian Aichelburg, Markus Arndt, Paolo Aschieri, Dorothea Bahns, Reinhold Bertlmann, Daniel Blaschke, Maja Buric, Christoph Dellago, Gerhard Ecker, Peter Falkensteiner, Reinhard Folk, Krzysztof Gawedzki, Fritz Gesztesy, Gebhard Grübl, Beatrix Hiesmayr, Regina Hitzenberger, Harald Iro, Gerald Kelnhofer, Daniela Klammer, Matthias Kornexl, Maximilian Kreuzer, Giovanni Landi, Christian Lang, Edwin Langmann, Gandalf Lechner, Wolfgang Lucha, Albert Much, Heide Narnhofer, Harald Rindler, Vincent Rivasseau, Heinz Rupertsberger, Christian Rupp, Karl-Georg Schlesinger, Martin Schlichenmaier, Klaus Schmidt, Volker Schomerus, Peter Schupp, Harold Steinacker, Alexander Strohmaier, Walter Thirring, Fabien Vignes-Tourneret, Michael Wohlgenannt, Raimar Wulkenhaar, George Zoupanos.

Recent Advances in Integrable Systems of Hydrodynamic Type

Organizers: A. Constantin (Vienna), J. Escher (Hannover)

Dates: October 12 - 23, 2009

Budget: ESI € 11.810,–, University of Vienna € 7.000,–

Report on the programme

The program explored recent research advances in integrable systems of hydrodynamic type. A prominent role was devoted to studies of two recently derived nonlinear models for shallow water waves — the Camassa-Holm equation and the Degasperis-Procesi equation — but other important aspects of water waves were discussed as well. Of special interest were integrability aspects (scattering theory, solitons), infinite-dimensional Hamiltonian systems, Lie-Poisson structures on the diffeomorphism group of the circle, and qualitative studies of the governing equations for water waves (resonance and steady waves). Other than pure and applied mathematicians, several theoretical physicists participated in the program and this permitted a rich exchange of ideas. As an indication of the fruitful interaction of the participants, three ESI-preprints were already submitted:

1. R. Johnson and L. Zampogni, *On the Camassa-Holm and KdV hierarchies* (ESI-preprint 2201).
2. A.-V. Matioc, *On particle trajectories in linear water waves*, submitted on (ESI preprint 2222).
3. V. S. Gerdjikov and G. Grahovski, *Multi-component NLS models on symmetric spaces: spectral properties versus representations theory*, submitted on (ESI-preprint 2226).

In addition, a special issue of the journal *Discrete and Continuous Dynamical Systems - Series B* published as volume 12, number 3, in October 2009, (ISSN 1531-3492) appeared as a theme issue of research papers related to the programme.

Invited Scientists: Christer Bennewitz, Mats Ehrnstroem, Vladimir Gerdjikov, Georgi Grahovski, David Henry, Delia Ionescu-Kruse, Rossen Ivanov, Russell Johnson, Elena Kartashova, Boris Kolev, David Lannes, Olaf Lechtenfeld, Jonatan Lenells, Anca Matioc, Bogdan Matioc, Anders Melin, Luc Molinet, Octavian Mustafa, Xavier Raynaud, Artur Sergyeyev, Eugen Varvaruca, Gabriele Villari, Erik Wahlen, Marcus Wunsch, Luca Zampogni.

Kontexte: Abschlusstagung des Initiativkollegs "Naturwissenschaften im historischen Kontext"

Organizers: M. Ash (Vienna), G. Müller (Vienna/Altenberg), E. Nemeth (Vienna), C. Pias (Vienna/Berlin), C. Sachse (Vienna), F. Stadler (Vienna).

Dates: November 27 - 28, 2009

Report on the programme

The closing conference of the *Initiativkolleg "Sciences in Historical Context"*, a PhD- Programme of the University of Vienna, was co-organized and hosted by the ESI. The Initiativkolleg, funded by the *Austrian Science Fund* (FWF) jointly with the University of Vienna, started in fall of 2006 with 12 students. The participants of the Initiativkolleg presented their PhD-theses at the closing conference in the *Schrödinger Lecture Hall* on November 27 and 28, 2009.

6th Vienna Central European Seminar on Particle Physics and Quantum Field Theory: Effective Field Theories

Organizer: H. Hüffel (University of Vienna). Advisory Board: Gino Isidori (Frascati), Wolfgang Lucha (Vienna), Helmut Neufeld (Vienna), Anton Rebhan (Vienna).

Dates: November 27 - 29, 2009

Budget: ESI €2.000,–. Also supported by the High Energy Physics Institute of the Austrian Academy of Sciences, the Faculty of Physics (University of Vienna), the Vienna University of Technology, the Vienna Convention Bureau, Flavianet and by Heptools.

Preprints contributed: [2207], [2206], [2205]

Report on the programme

The presentations were centered on chiral perturbation theory, soft collinear effective theory, nonrelativisitc QCD and hadronic atoms. In addition recent advances in effective field theory methods for the deconfinement phase transition and in electroweak symmetry breaking are discussed. The seminar covered experimental and theoretical aspects.

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

Invited talks:

Thorsten Feldmann (Munich): "Soft-Collinear-Effective-Theory and B-Meson Decays"

Jürg Gasser (Bern): "Chiral Perturbation Theory"

Christophe Grojean (CERN): "Hunting the Higgs and Beyond"

Hans-Werner Hammer (Bonn): "Universal EFT for strongly interacting quantum systems"

André Hoang (Munich): "Soft-Collinear-Effective-Theory and Jets at Colliders"

Aleksi Kurkela (Zurich): "Dimensional reduction near the deconfinement transition"

Akaki Rusetsky (Bonn): "Hadronic Atoms"

Stefan Scherer (Mainz): "Baryon chiral perturbation theory"

Antonio Vairo (Munich): "Effective field theories for non-relativistic bound states"

Aleksi Vuorinen (CERN): "A new Approach to Effective Field Theory for Few-Nucleon Physics"

Public Lecture:

Christian Fabjan (Vienna): "Experimental Particle Physics: the Next Ten Years"

(Un)Conceived Alternatives. Underdetermination of Scientific Theories between Philosophy and Physics

Organizers: M. Arndt (Vienna), R. Dawid (Vienna), E. Nemeth (Vienna), W. Reiter (Vienna), D. Romizi (Vienna), F. Stadler (Vienna)

Dates: December 18 - 19, 2009

Report on the programme

As a joint initiative of philosophers of science and physicist at the University of Vienna, in cooperation with the ESI (W. L. Reiter and J. Yngvason) an interdisciplinary symposium on the topic *(Un)Conceived Alternatives: Underdetermination of Scientific Theories between Philosophy and Physics* was held on 18 and 19 December, 2009 at the ESI.

The symposium aimed to initiate and foster a discussion between physicists and philosophers of science, in particular on the topic of underdetermination. Papers were presented in two sessions, (1) Physics and (2) Philosophy of Science. Abstracts and slides of the talks are available at http://think.univie.ac.at/abstractsslides/

Speakers and topics in Physics

Markus Arndt (Vienna): "Underdeterminedness and the quantum superposition of massive objects"; Markus Aspelmeyer (Vienna): "Underdetermination in quantum physics"; Daniel Grumiller (Vienna): "Cosmology in the multiverse"; Manfred Jeitler (Vienna): "Particle physics: from an experiment-driven to a theory-driven field"; Karl Landsteiner (Madrid): "The dual use of string theory"; Jakob Yngvason (Vienna): "Lessons from quantum field theory".

Speakers and topics in Philosophy of Science

Richard Dawid (Vienna): "Limitations to underdetermination of theory building and their role in fundamental physics"; Brigitte Falkenburg (Dortmund): "Underdetermination and the phenomena of physics"; Paul Hoyningen-Huene (Hannover): "The miracle argument and transient underdetermination"; Elisabeth Nemeth (Vienna): "Is there any use physicists can make of philosophy of science? Re-considering Philipp Frank on science teaching"; Miklos Redei (Budapest and London): "Diachronic underdetermination in the development of relativistic quantum field theory"; Kyle Stanford (Irvine): "Bush's nightmare: where (and when) do unconceived alternatives pose a serious challenge to scientific knowledge?".

Junior Research Fellows Programme

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

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

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

1st deadline: 17.04.2009
Number of applications: 44
Number of accepted applicants: 13
Number of months granted: 32 for 2009, 14 for 2010

2nd deadline: 11.10.2009
Number of applications: 20
Number of accepted applicants: 7
Number of months granted: 24 for 2010

Junior Research Fellowships in 2009

Name	Gender	Duration	Nationality
Lior Alexandra Aermark	female	05/07 - 20/07	Israel
Jose Aliste	male	01/09 - 31/12	Chile
Emanuela Bianchi	female	01/03 - 31/08	Italy
Francis Brown	male	01/03 - 19/04	Great Britain
Claudio Dappiaggi	male	01/10 - 31/12	Italy
Slawomir Dinew	male	01/10 - 31/12	Poland
Zywomir Dinew	male	01/10 - 31/12	Poland
Anastasia Jivulescu	female	01/08 - 31/10	Romania
Lukasz Kosinski	male	01/10 - 31/12	Poland
Rongmin Lu	male	01/03 - 30/04	Singapore
Anca Matioc	female	01/10 - 31/10	Romania
Kostyantyn Medynets	male	01/03 - 31/05	Ukraine
Karin Melnick	female	17/04 - 13/06	USA
Wolfgang Moens	male	05/10 - 31/12	Belgium
Mathieu Molitor	male	01/01 - 31/03	France
Milan Mosonyi	male	01/01 - 31/03	Hungary
Carolina Neira	female	01/03 - 30/04	Colombia
Nicolas Raymond	male	10/05 - 10/07	France
Jean Ruppenthal	male	15/10 - 23/12	Germany
Josef Silhan	male	01/01 - 28/02	Czech Republic
Jean-Charles Sunye	male	15/10 - 31/12	France
Kirsten Vogeler	female	01/03 - 30/06	Germany
Zhituo Wang	male	01/03 - 30/06	China
Jiangyang You	male	01/03 - 30/06	China
Lenka Zalabova	female	01/01 - 31/01	Czech Republic
Lei Zhang	male	01/01 - 28/02	China
Magdalena Zych	female	01/03 - 30/06	Poland

Preprints contributed: [2088], [2109], [2130], [2134], [2135], [2136], [2154], [2168], [2198], [2202], [2203]

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:

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

Raimar Wulkenhaar (Universität Münster), Summer 2009: *Spectral triples in noncommutative geometry and quantum field theory*

Michael Loss (Georgia Tech Atlanta), Summer 2009: *Spectral inequalities and their applications to variational problems and evolution equations*

Peter West (King's College, London), Winter 2009/10: *Supergravity Theories*

Jeff McNeal (Ohio State University, Columbus), Winter 2009/10: L^2 *methods in complex analysis*

Longterm Visitors within the Senior Research Fellowship Framework:

Marie France Vigneras (Université de Paris 7), January 2 - February 28, 2009

Don Blasius (UCLA, Los Angeles), January 4 - March 23, 2009

Pavel Zalesskii (University of Brasilia), January 5 - 31, 2009

Spyridon Kamvissis (University of Crete, Heraklion), April 2 - May 31, 2009

Bernard Helffer (Université Paris-Sud, Orsay), May 2 - July 25, 2009

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

Course: The course was devoted to the study of square integrable automorphic forms for a semisimple algebraic group G over a number field k. The square integrable automorphic forms are defined in the style of Harish–Chandra who emphasizes their role in the spectral decomposition of the corresponding L^2 space $L^2(G(k)\backslash G(\mathbb{A}))$ where $\mathbb{A}$ is a ring of adeles of k. We discuss the relation to the corresponding space $L^2(\Gamma\backslash G_\infty)$ of square–integrable functions on $\Gamma\backslash G_\infty$, where G_∞ is the group of $\mathbb{R}$–points of a $\mathbb{Q}$–group $Res_{k/\mathbb{Q}}$ obtained by restriction of scalars and Γ is a congruence subgroup of G_∞. Special attention was given to the question regarding existence and construction of cuspidal automorphic forms which are the most important example of square integrable automorphic forms.

We covered the following subjects:

- Basic notions in the analysis on $G(\mathbb{A})$: measures, the decomposition of the measures into local components, the notion of the measure on $G(k)\backslash G(\mathbb{A})$, the notion of C^∞ functions on $G(\mathbb{A})$.
- The relation between open–compact subgroups of the group of finite adeles $G(\mathbb{A}_f)$ and congruence subgroups of G_∞.
- Basic notions in the theory of unitary representations of locally compact groups with applications to the right regular representations $L^2(\Gamma\backslash G_\infty)$ and $L^2(\Gamma\backslash G_\infty)$.

- A discussion of the $(\mathfrak{g}_\infty, K_\infty)$–module associated to an irreducible subrepresentation of $L^2(\Gamma\backslash G_\infty)$ and the notion of the space of all square–integrable automorphic forms $\mathcal{A}^2(\Gamma\backslash G_\infty)$. The decomposition of $\mathcal{A}^2(\Gamma\backslash G_\infty)$ into irreducible $(\mathfrak{g}_\infty, K_\infty)$–modules and the relation to the decomposition of the discrete part of $L^2(\Gamma\backslash G_\infty)$ into irreducible representations. Two fundamental results of Harish–Chandra. The analogous notion and results in the adelic setting $\mathcal{A}^2(G(k)\backslash G(\mathbb{A}))$.
- The notion of a cuspidal automorphic form and fundamental results concerning the decomposition of the corresponding spaces $\mathcal{A}_{cusp}(\Gamma\backslash G_\infty)$, $L^2_{cusp}(\Gamma\backslash G_\infty)$, $\mathcal{A}_{cusp}(G(k)\backslash G(\mathbb{A}))$, and $L^2_{cusp}(G(k)\backslash G(\mathbb{A}))$.
- The construction of cusp forms via L^1–Poincaré series in the case that G_∞ has the same rank as one of its maximal compact subgroup K_∞.
- The question of existence of cusp forms in $L^2_{cusp}(\Gamma\backslash G_\infty)$ using compactly supported Poincaré series.

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

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

The third paper in this series *On the cusp forms for the congruence subgroups of $SL_2(\mathbb{R})$*, (http://web.math.hr/~gmuic/vita/temp_cusp_forms_SL2.pdf) gives an application of the paper *Spectral Decomposition of Compactly Supported Poincaré Series and Existence of Cusp Forms* to study Maass forms for $SL_2(\mathbb{R})$. We show how to realize non–spherical principal series for $SL_2(\mathbb{R})$ as subrepresentations of $L^2(\Gamma(N)\backslash SL_2(\mathbb{R}))$ for $N \geq 3$, where $\Gamma(N)$ is the principal congruence subgroup of $SL_2(\mathbb{R})$. The papers are submitted to ESI preprint series.

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

Programme and Workshop organization: Together with J. Schwermer and G. Henniart I organized the programme *Representation Theory of Reductive Groups - Local and Global Aspects* that took place at ESI January 4 - February 28 2009. This programme focused on several aspects of the theory of automorphic representations. That theory possesses a very strong structure given by the Langlands program, in particular, the functoriality principle. This involves Galois or Weil group representations, the representation theory of local reductive groups, and questions regarding automorphic spectra. Recently there have been important developments which we intend to cover as well as current research. During the programme period we had weekly seminar activity and also a special two week period January 25-February 6 where we had a Workshop. The list of visitors as well as all the title and abstracts of all talks can be found on http://web.math.hr/~gmuic/programme_2009.html (currently this web page can be reached through http://www.esi.ac.at/activities/current-prog.html). It included approximately 40 people from various countries including Austria, France, Germany, Canada, USA, Great Britain etc.

Raimar Wulkenhaar: Spectral triples in noncommutative geometry and quantum field theory

I had the great honour and pleasure to spend the spring semester 2009 as Senior Researcher at the Erwin-Schrödinger-Institute. The stay was split into two periods 1 March – 3 April and 3 May – 19 June.

Course: I gave twice a week a lecture course on *Spectral triples in noncommutative geometry and quantum field theory*. The course was part of the ESI programme *Number theory and physics* from 1 March to 19 April organised by Alan Carey, *et al*. I have had 6–10 participants and one exam at the end.

The lecture course was divided into three parts: In the first part I presented the recently proved reconstruction theorem [1] of A. Connes. The theorem states that smooth oriented compact manifolds are in 1:1-correspondence with commutative spectral triples $(\mathcal{A}, \mathcal{H}, \mathcal{D})$. Here, $\mathcal{D}$ is a selfadjoint unbounded operator with compact resolvent on a Hilbert space $\mathcal{H}$, and $\mathcal{A}$ is an algebra also acting on $\mathcal{H}$ which is Fréchet with respect to derivatives induced by $\mathcal{D}$. I omitted the mostly technical steps of the proof and focused on the elegant construction of candidates for local charts.

In the second part I presented the spectral triple formulation of the standard model of particle physics. This formulation underwent a major change in 2006 with different metric and KO-dimensions. The new version gives geometric arguments [2] for the structure group of the standard model and naturally includes right-handed neutrinos.

The third part was devoted to Rieffel deformations [3] of spectral triples. This means that isometries of the underlying manifold are used to deform the algebra $\mathcal{A}$ into a noncommutative one, whereas $\mathcal{H}, \mathcal{D}$ are unchanged. The prototype is the noncommutative torus, but also the Connes-Landi sphere and the Moyal space are obtained in this way. Quantum field theories on such isospectral deformations are intensely studied.

Seminars: The first period in March-April was already filled with activities of the ESI programme "Number theory and physics". Therefore, I only organised one seminar talk by Daniel Blaschke (TU Vienna) on "Constructing renormalizable models for gauge fields in non-commutative space" (25 March).

I tried to invite several colleagues for seminar talks during the second period in May-June.

Unfortunately, only Thomas Krajewski (Marseille and Orsay) could accept this invitation. He stayed at ESI from 1 June to 5 June 2009 and gave a seminar talk on graph polynomials.

All other contacted colleagues were not able to come due to teaching constraints.

Research: I continued a joint research project with Harald Grosse on the non-perturbative construction of the self-dual ϕ^4-model on four-dimensional Moyal space with harmonic oscillator potential. In previous work [4] we had proven that this model is renormalisable to all orders in perturbation theory. We also showed that the one-loop β-function is zero [5]. In 2006, M. Disertori, R. Gurau, J. Magnen and V. Rivasseau proved [6] that the β-function vanishes to all orders in perturbation theory. The main tool in their proof is a combination of Schwinger-Dyson equations with a Ward identity for the group action of infinite matrices. With H. Grosse we have been working from time to time since 2007 to extend the result of Disertori et al. to a full non-perturbative construction of the two-point function of the model. In 2007 we had already derived a self-consistent non-linear equation for the two-point function alone, using Schwinger-Dyson equations and Ward identity. But essentially no advance with this equation was made in the following two years. During the Senior Fellowship we made considerable progress.

The first step was to perform the renormalisation directly in the equation for the two-point function. The second step was to replace sums by integrals, which permits a perturbative evaluation of the renormalised two-point function. The perturbative calculation suggested a change-of-variables in which the equations are particularly simple. The central result is the following

Theorem 1 *The renormalised planar connected two-point function $G_{\alpha\beta}$ of self-dual noncommutative ϕ^4_4-theory (with continuous indices) satisfies the integral equation*

$$
\begin{aligned}
G_{\alpha\beta} = 1 + \lambda\Big(& \frac{1-\alpha}{1-\alpha\beta}\big(\mathcal{M}_\beta - \mathcal{L}_\beta - \beta\mathcal{Y}\big) + \frac{1-\beta}{1-\alpha\beta}\big(\mathcal{M}_\alpha - \mathcal{L}_\alpha - \alpha\mathcal{Y}\big) \\
& + \frac{1-\beta}{1-\alpha\beta}\Big(\frac{G_{\alpha\beta}}{G_{0\alpha}} - 1\Big)\big(\mathcal{M}_\alpha - \mathcal{L}_\alpha + \alpha\mathcal{N}_{\alpha 0}\big) - \frac{\alpha(1-\beta)}{1-\alpha\beta}\big(\mathcal{L}_\beta + \mathcal{N}_{\alpha\beta} - \mathcal{N}_{\alpha 0}\big) \\
& + \frac{(1-\alpha)(1-\beta)}{1-\alpha\beta}(G_{\alpha\beta} - 1)\mathcal{Y}\Big)\;,
\end{aligned}
$$

where $\alpha, \beta \in [0,1)$,

$$
\mathcal{L}_\alpha := \int_0^1 d\rho\, \frac{G_{\alpha\rho} - G_{0\rho}}{1-\rho}\;, \qquad \mathcal{M}_\alpha := \int_0^1 d\rho\, \frac{\alpha\, G_{\alpha\rho}}{1-\alpha\rho}\;, \qquad \mathcal{N}_{\alpha\beta} := \int_0^1 d\rho\, \frac{G_{\rho\beta} - G_{\alpha\beta}}{\rho-\alpha}\;,
$$

and $\mathcal{Y} = \lim_{\alpha\to 0} \frac{\mathcal{M}_\alpha - \mathcal{L}_\alpha}{\alpha}$.

We computed $G_{\alpha\beta}$ perturbatively to order λ^3. The result is a polynomial with rational coefficients in α, β, $\frac{1-\alpha}{1-\alpha\beta}$, $\frac{1-\beta}{1-\alpha\beta}$, zeta-functions and iterated integrals labelled by rooted trees which evaluate to polylogarithms:

$$
\begin{aligned}
I_\alpha &:= \int_0^1 dx\, \frac{\alpha}{1-\alpha x} = -\ln(1-\alpha)\;, \\
I_{\overset{\alpha}{\bullet}} &:= \int_0^1 dx\, \frac{\alpha\, I_x}{1-\alpha x} = \mathrm{Li}_2(\alpha) + \frac{1}{2}\big(\ln(1-\alpha)\big)^2 \\
I_{\overset{\alpha}{\bullet\,\bullet}} &= \int_0^1 dx\, \frac{\alpha\, I_x \cdot I_x}{1-\alpha x} = -2\,\mathrm{Li}_3\Big(-\frac{\alpha}{1-\alpha}\Big)\;, \\
I_{\overset{\alpha}{\substack{\bullet\\ \bullet}}} &= \int_0^1 dx\, \frac{\alpha\, I_{\overset{x}{\bullet}}}{1-\alpha x} = -2\mathrm{Li}_3\Big(-\frac{\alpha}{1-\alpha}\Big) - 2\mathrm{Li}_3(\alpha) - \ln(1-\alpha)\zeta(2) \\
&\qquad + \ln(1-\alpha)\mathrm{Li}_2(\alpha) + \frac{1}{6}\big(\ln(1-\alpha)\big)^3\;.
\end{aligned}
$$

Similar iterated integrals appeared in toy models for the Hopf algebra of Connes-Kreimer (where the root is above). The self-dual noncommutative ϕ^4_4-theory thus provides another example for the deep connection between number theory and physics. We published a preprint [7] with these results.

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Michael Loss: Spectral inequalities and their applications to variational problems and evolution equations

Course: While it is rather standard to use functional inequalities to study the existence of flows, the opposite, namely to derive functional inequalities using flow techniques has been developed only in the past few years. While one cannot say that this approach is universal, it has delivered rather simple proofs for inequalities in their sharp form that have been considered as hard and deep results. The precursor of some of these techniques has been 'Competing Symmetries; discovered by Eric Carlen and myself and which delivered soft proofs of a whole slew of conformally invariant inequalities in their sharp form including all the cases of equality. Examples are the sharp Hardy-Littlewood-Sobolev inequality of Lieb as well as Onofri's inequality and its generalization to higher dimensions. It has gained additional impetus from developments in transportation theory which yields new insight into the structure of some of these results.

In the two month long course held during the spring and summer 2009, a number of interesting problems coming from the interplay mentioned were explained. The course material can be found on http://people.math.gatech.edu/ loss/ESIVORLESUNG/esilectures.html.

Brascamp-Lieb inequalities

I started with the Brascamp-Lieb inequalities, which are, one could say ubiquitous. They are used in statistics, in geometry and, as generalizations of Young's inequality, they appear naturally in analysis and in problems related to partial differential equations. One approach, due to Franck Barthe, uses transportation theory while another proof proceeds via a non-linear heat flow that reduces the problem to an inequality about Gaussian functions. This was done by Carlen-Lieb-Loss in the rank one case and by Bennett-Carbery-Christ-Tao and Valdimarsson in the general case.

The transportation approach was presented in the simplest case and from this the sharp form of Young's inequality as well as its 'infinitesimal version', namely Gross' logarithmic Sobolev inequality was derived. As an illustration the logarithmic Sobolev inequality was then used to obtain optimal smoothing estimates for the two dimensional Navier Stokes equations, a result due to Carlen and myself. Sharp means not just the right exponents for the decay in time, but also the correct constants which are the same as the one appearing in the smoothing estimates of the heat equation.

Another topic related to the Brascamp-Lieb inequalities is its connection to convex geometry, as discovered by Keith Ball. In the lectures we considered the following problem. Among all convex and symmetric bodies that have volume one, find the one whose largest inscribed ellipsoid has smallest volume, i.e., maximize the ratio of the volume of a convex set with the volume of its largest inscribed ellipsoid. The answer among symmetric sets is the n-dimensional cube, as proved by Ball.

Along the way, a few things had to be explained. Among them the theorem of Fritz John concerning the points of contact between the largest inscribed ellipsoid with the boundary of the body. This required reviewing a number of concepts from convexity, such as the Hahn-Banach separation theorem. As it turns out, these John-points lead to a very nice formulation of a version of the Brascamp-Lieb inequalites, again due to Ball. It serves as a particularly simple and useful application of the non-linear heat flow method and I presented a detailed proof of this result.

Competing symmetries

In the second part of the course I talked about competing symmetries. As a preamble, rearrangement of functions had to be explained, in particular a number of rearrangement inequalities such as the Riesz rearrangement inequalitiy were proved. The composition of rearrangement with conformal transformations leads to an L^p isometry and, surprisingly, this isometry when iterated on L^p drives functions to a unique fix point. The sharp Hardy-Littlewood-Sobolev inequality is an easy consequence of this operation.

Transportation theory

As a last topic I discussed transportation theory reviewing work of Brenier and McCann. This entails a number of interesting topics such as the Birkhoff-von Neumann theorem which is a relatively straight forward consequence of a combinatorial theorem usually attributed to Hall (1935) but already known to Koenig (1916). These theorems solve the transportation problem for discrete measures and since convex combinations of those are weak * dense in the space of measures one obtains the general case in a straightforward fashion. This is essentially the approach of McCann.

Research: One area of my research concerns sharp inequalities for fractional derivatives. This area has gained some popularity for a number of reasons. One is quantum mechanics for relativstic models where the kinetic energy is essentially the square root of the Laplace operator. Further, fractional derivative operators are generators for stochastic processes, the Lévy processes. In joint work with my student Craig Sloane I established a sharp Hardy inequality for fractional derivatives of functions that are localized in arbitrary domains. A conjecture of Bogdan and Dyda concerning sharp Hardy inequalities for fractional derivatives for functions with support on convex domains is a consequence of our new inequality. A version of the paper can be found at http://arxiv.org/abs/0907.3054.

Peter West: Supergravity Theories

I gave ten lectures on supersymmetry and supergravity and in particular the maximal supergravity theories in eleven, ten and lower dimensions. The ten dimensional theories are the complete low energy effective actions for the type II superstring theories and, although constructed long ago, they have played a key role in our current understanding of string theory. The lecture course contained the following topics: a review of Clifford algebras, the Noether and gauging methods of constructing supergravity theories, the four dimensional $N = 1$ supergravity theory and a proof of its invariance under supersymmetry, presentation of the eleven dimensional and IIA and IIB supergravity theories and their properties, a review of the theory of non-linear realisations and torus dimensional reduction.

I carried out research on the relation between non-holomorphic automorphic forms and string theory. The content of the paper which is about to be published is as follows. We have used our previous construction of Eisenstein-like automorphic forms Φ for any representation and group to derive formulae for the perturbative and non-perturbative parts. The result is written in terms of the weights of the representation and the derivation is largely group theoretical. Specialising to the E_{n+1} groups relevant to type II string theory and the representation associated with node $n+1$ of the E_{n+1} Dynkin diagram we explicitly find the perturbative part in terms of string theory variables, such as the string coupling g_d and volume V_n. For dimensions seven and higher we find that the perturbation theory involves only two terms. In six dimensions we construct the $SO(5,5)$ automorphic form using the vector representation. Although these automorphic forms are generally compatible with string theory the one relevant to R^4 involves terms with g_d^{-6} and so is incompatible. We then study a constrained $SO(5,5)$ automorphic form, obtained by summing over null vectors, and compute its perturbative part. We find that it is consistent with string theory and makes precise predictions for the perturbative results. We also study the unconstrained automorphic forms for E_6 in the **27** representation and E_7 in the **133** representation, giving their perturbative part and commenting on their role in String Theory.

I also took part in many discussions and seminars at the Vienna University of Technology with members of the theoretical physics group and I hope that this will lead to a publication when I visit again. I also gave a seminar on E_{11} symmetry and string theory at the University.

Jeff McNeal: L^2 methods in complex analysis

Course: From October 28 through November 20, 2009, I gave an advanced course titled "L^2 methods in complex analysis" at the Ewrin Schrödinger Institut. The goal of the course was to give a working introduction to basic L^2 estimates on the Cauchy-Riemann equations, at a level suitable for postdoctoral mathematicians working in complex analysis. Several advanced graduate students also attended the course and additional background material was given to these participants, to assist them in following the pace of the course.

The so-called "twisted" L^2 estimates for $\bar\partial$ were the main focal point for the course. These estimates — due to Ohsawa-Takegoshi, McNeal, Berndtsson, and Siu, in different contexts — were discovered during the last twenty years and have not yet appeared in advanced textbooks. Earlier, fundamental inequalities for $\bar\partial$ — due to Kohn, Hörmander, and Kodaira — were also discussed, in order to motivate the twisted estimates and to highlight the new features that the twisted estimates possess. In the lectures, the emphasis was on explaining how the twisted estimates are obtained, how they lead to certain applications unattainable by prior estimates, and the flexibility inherent in the twisted method. The general goal was encourage participants in the course toward as yet untapped applications of the twisted estimates.

I gave 20 hours of lectures for this course during my stay at the ESI. Of these, 16 hours were formal lectures that were also attended by many of the senior mathematicians visiting the ESI and 4 hours were more informal, problem sessions given only to the postdoctoral participants in the course. Printed lecture notes were given to all participants in the ESI course. These notes were skeletal, primarily consisting of definitions, notation, and statement of results, but the enthusiastic feedback from students in the course will be helpful in their later planned expansion to a manuscript. Additionally, 3 hour-long lectures were given by current or former graduate students of mine in support of the ESI course:

· Anne-Katrin Herbig, "Global regularity of the Bergman projection on forms"

· Yunus Zeytuncu, "Multiplier ideals and integral closure of monomial ideals"

· Janhavi Joshi, "L^2 cohomology vanishing theorems via weighted inequalities"

These lectures illustrated specific applications of the estimates developed in my course.

Research: I spent a large portion of my time preparing the lectures and notes for my course. However, I also was able to complete two research projects, begun earlier, with collaborators who were also at the ESI during my stay. The resulting papers from these projects are

McNeal, J.D. & Zeytunuc, Y.E., *Multiplier ideals and integral closure of monomial ideals : an analytic approach*, 15 pages (preprint)

Herbig, A.-K. & McNeal, J.D., *Convex defining functions for convex domains*, 22 pages (preprint)

Both papers were submitted to the ESI preprint server.

I spent several hours each week with the ESI Junior Fellows, listening to their current research projects and offering guidance or technical assistance to them when possible. I reconnected with many more senior colleagues and friends while at the ESI, and we renewed our ongoing discussions about complex analysis and differential equations. The conversations with Boas, D'Angelo, and Kohn were especially productive. I also gave a Colloquium at the University of Vienna during my stay.

Finally, I'd like to acknowledge how valuable it was to have my three current graduate students at the ESI during my time as Senior Fellow. (I used all the "visitor funds" allocated to my Senior Fellowship to support these students, partially because the organizers of the program — Bernhard Lamel and Friederich Haslinger — had already done such an outstanding job inviting the senior mathematicians I wanted to interact with.) All three students are quite advanced and will graduate with PhDs within a year. All three made great progress on their theses while at the ESI, and I was able to give them daily feedback on their work since we were all at the Institute together. Perhaps even more valuable was the experience my students had in meeting some of the current leaders in the field while at the ESI. This experience inspired them last Fall to work unusually hard on their theses, but the lasting value of connecting with these mathematicians will serve them far into the future.

Marie France Vigneras

I discussed with Alberto Minguez and Vincent Secherre on the mod ℓ-representations of p-adic reductive groups and on my unpublished construction of the Brauer character of an irreducible $\overline{F}_p$-representation of G.

Most of the time I studied the induction from P^- to P of an etale representation M of the monoid $P^+ = T^+N(Z_p)$ (a generalized etale (phi, Gamma)-module) where $P = TN$ is a Borel subgroup of $G(Q_p)$. The etale action of P^+ on M has a left inverse which is an action of the monoid P^-. The induction from P^- to P is an exact functor. The classical model of the induced representation by functions from $P(Q_p)$ to M with an equivariance property, restricted to the submonoid s^N for $s \in T$ strictly contracting, is the $\psi^\infty(M)$ model of M^P introduced by Colmez for $GL(2)$. Its restriction to the subgroup $N(Q_p)$ is also an isomorphism with the induction M^N from $N(Z_p)$ to $N(Q_p)$ of M, that I call the N-model. The N-realization allows to simplify and to generalize the constructions of Colmez given in the ψ^∞-model. For example, the "restrictions" are projectors associated to open compact subgroups of $N(Q_p)$ and induce a measure on $N(Q_p)$ with values in $End(M^P) = End(M^N)$. Another example is the subspace of functions with compact support in the N-model. Or when M is complete Hausdorff and linear topological with an etale continuous action of P^+, the subspace $\tilde{M}^N$ of functions vanishing at infinity in the

N-model, and the subspace of functions converging at infinity in the s-model, generalize certain ad hoc constructions of Colmez.

The Iwasawa algebra Λ of $N(Z_p)$ is naturally an etale representation of P^+. I showed that $\tilde{\Lambda}^N$ is a topological ring and that $\tilde{M}^N$ is a topological $\tilde{\Lambda}^N$-module for the uniform convergence topology, for any complete $\Lambda(N_0)$-module. This algebra $\tilde{\Lambda}^N$ for $GL(2, Q_p)$ was constructed by Fontaine with a totally different method and plays an important role.

The microlocalized algebra Λ_ℓ of Λ associated to a generic character $\ell : N(Q_p) \to Z_p$ is naturally an etale representation of P^+ which was introduced in my work with Schneider. Under a natural assumption (H) on bounded subsets of Λ_ℓ, I showed that $\tilde{\Lambda}_\ell^N$ is a topological ring and that $\tilde{M}^N$ is a topological $\tilde{\Lambda}_\ell^N$-module for the uniform convergence topology, for any complete $\Lambda_\ell(N_0)$-module.

The assumption (H) is trivially satisfied when $N(Z_p)$ is commutative. I left Vienna without the open problem of describing the obstructions for the assumption (H).

My work in Vienna is part of a common project with Peter Schneider. Vienna was a very nice and comfortable place to work, to make progress, to discuss, and to live. I am very thankful for the invitation to the ESI.

Don Blasius

This was a productive and interesting visit with numerous significant interactions with colleagues in my field. My research has, in recent years, focused on automorphic Galois representations. The construction of these representations is made on the basis of accumulated deep knowledge of both the local and global aspects of the representation theory of reductive groups, which was the theme of the program.

During the program, my principal research concerned the determination of the reductive group defined by the Zariski closure of an automorphic Galois representation. In particular, I speculate that, under the condition (in the characteristic zero case; there is no such condition in characteristic p) that the representations counted be cohomological, the asymptotic density, computed relative to the conductor, of those for which this group is maximal, is one. During the program I: (i) found most elements of a new strategy to prove the conjecture for GL(N) in the function field case; (ii) worked on the proof for GL(2), GU(3) and GSp(4) over a totally real field; (iii) worked on proofs of weaker (just positive density) results for all unitary groups using local methods, i.e. using the Harris-Taylor-Henniart local Langlands correspondence. For (i) and (ii) one must proceed by direct computation of the densities of the non-full forms. This method cannot work at this point in general so various tricks especially using the fact that at a prime p, the local components at p of the forms in a suitable tower are distributed according to Plancherel measure. Proof of this latter fact in generality was a major topic of my research and conversations. In fact, the general result was announced by Sug Woo Shin in Fall 2009 by a method very similar, using the trace formula, to that I envisioned.

During the program, in addition to benefiting from the workshops, I had productive discussions with Joachim Schwermer, James Cogdell, Marie-France Vigneras, Michael Rapoport, Erez Lapid, Freydoon Shahidi, Peter Schneider, Jean-Pierre Labesse, A. Raghuram, and Guenter Harder. Each of these is an expert of global significance in their area. With this group, the concentration of expertise at hand with relevance to my work was perfect. I of course spoke to numerous other people, especially younger ones, but these colleagues of long-standing acquaintance were those with whom I spoke the most. I should point out that I was permitted to stay 3 weeks beyond the end of the program, and so enjoyed a time of quiet concentration. This was of great value as well.

Finally, I would like to comment that in addition to having brought the right group of people together, in all practical organizational matters connected with visitors -such as accommodationsand workshops, office space, etc., the ESI administration of Schwermer and Schmidt, especially including the office team led by the very competent Isabella Miedl, is about the best I have encountered in many visits around the world.

Pavel Zalesskii

The wonderful stimulating environment of the Erwin Schrödinger Institute gave me the opportunity to work intensively and write in collaboration with W.N. Herfort three papers (one is published, two are in preparation). The time spend in the institute was very valuable for finishing several papers: in collaboration with Dessislava Kochloukova, Henry Wilton, Laurent Bartoldi and advance on the paper with Thomas Weigel.

In the paper with Wolfgang Herfort we study virtually free pro-p groups with the objective to obtain the pro-p analogue of a description due to Karras, Pietrovski, Solitar, Cohen and Scott of an abstract virtually free group.

In the first paper "Virtually free pro-p Groups need not be the fundamental group of a graph of finite p-groups", Archiv der Mathematik Volume 94, No.1/January, 2010 DOI 10.1007/s00013-009-0063-y, pp. 35-41, we prove that the pro-p version of the Karras, Pietrovski, Solitar, Cohen and Scott result does not hold in the case of an infinitely generated group. Namely, we construct a subgroup of a finitely generated virtually free pro-2 group $D_4 \amalg_{C_2} (C_2 \times C_2)$ contains a closed subgroup H which cannot be presented as the fundamental pro-2 group of a profinite graph of finite 2-groups. One of the main results of Bass-Serre theory is a theorem of Bass that says that every subgroup of the fundamental group of a graph of groups is again the fundamental group of a canonically constructed graph of groups. Our example gives a countably generated counter-example to the pro-p version of the theorem of Bass for subgroups of the fundamental group of a smallest possible graph of finite p-groups. Our counter-example can be adapted to the situation of pro-p groups for $p \neq 2$.

The second paper contains a proof of the pro-p version of the Karras-Pietrovski-Solitar statement for any finitely generated pro-p group. The result can be considered as a natural generalization of Serre's result saying that every torsion free virtually free pro-p group is free pro-p.

As a consequence we obtain that a finitely generated virtually free pro-p group is the pro-p completion of a virtually free discrete group. However, the discrete result is not used (and cannot be used) in the proof.

V.A.Romankov proved in 93 that the automorphism group of a finitely generated free pro-p group $Aut(\widehat{F}_n)$ of rank $n \geq 2$, is topologically infinitely generated. Nevertheless, our result allows us to show that, surprisingly, the number of conjugacy classes of finite p-subgroups in $Aut(\widehat{F}_n)$ is not greater than the corresponding number for $Aut(F_n)$.

Certain ideas developed in the second paper gave start to the third paper on surgery of profinite trees. The objective of developing this is to dribble the problem of the impossibility to collapse finite subtrees (including edges) in the profinite version of the Bass-Serre theory of groups acting on trees. The developed methods should help to split groups acting on pro-p trees in the amalganated free pro-p product or HNN-extension.

I also managed to finish the manuscript of the paper (joint with Dessislava Kochloukova), where the study of pro-p limit groups initiated. The mathematical part of the paper was finished in fact during the workshop on profinite groups held in ESI, December, 2007. The paper was accepted in Math. Zeitsrift.

A written text of the result obtained during mentioned worksdhop on non-goodness of infinite elementary abelian groups. A group G is called good (J-P, Serre, Galois Cohomology) if the natual homomorphism $G \longrightarrow \widehat{G}$ induces the cohomology isomorphisms $H^n(\widehat{G}, M) \longrightarrow H^n(G, M)$

for all finite G-modules M and all n. It is kind of surprising that elementary abelian infinite groups are not good; the map already failed to be an isomorphism for $n = 2$. In fact, we deduce that an infinite elementary abelian p-group have uncountably many non-residually finite central extensions with the kernel of order p.

The time spent in the istitute also permitted me to finish two papers: one is jointly with Henry Wilton on conjugacy separability of graph manifolds (accepted in Geometriae Dedicata) and the second one is joint with Laurent Bartoldi and Olivier Siegenthaler about the conguence subgroup problem for groups acting on rooted trees.

Spyridon Kamvissis

Part of my research during the months April-May 2009 was done with Prof. Gerald Teschl. It continues earlier research [1], [2], concerning the following problem: let the purely periodic Toda lattice (of period N) be given by the equations

$$\begin{aligned} \dot b^q_n &= 2(a^q_n)^2 - 2(a^q_{n-1})^2, \\ \dot a^q_n &= a^q_n(b^q_{n+1} - b^q_n), \\ a^q_{N+n} &= a^q_n, \quad b^q_{N+n} = b^q_n. \end{aligned}$$

Consider also the doubly infinite Toda lattice

$$\begin{aligned} \dot b_n &= 2(a_n^2 - a_{n-1}^2), \\ \dot a_n &= a_n(b_{n+1} - b_n), \\ n &\in \mathbb{Z}, \end{aligned}$$

with initial data such that the first moment of the difference to the periodic lattice is finite

$$\sum_n |n|(|a_n - a^q_n| + |b_n - b^q_n|) < \infty$$

at time $t = 0$. The question is the behavior of a_n, b_n when $t \to \infty$.

The answer given in [1] is as follows: let g be the genus of the hyperelliptic curve associated with the unperturbed solution. We have shown that, apart from the phenomenon of the solitons travelling on the quasi-periodic background, the n/t-pane contains $g + 2$ areas where the perturbed solution is close to a finite-gap solution in the same isospectral torus. In between there are $g + 1$ regions where the perturbed solution is asymptotically close to a modulated lattice which undergoes a continuous phase transition (in the Jacobian variety) and which interpolates between these isospectral solutions. In the special case of the free lattice ($g = 0$) the isospectral torus consists of just one point and we recover the known result. Both the solutions in the isospectral torus and the phase transition are explicitly characterized in terms of Abelian integrals on the underlying hyperelliptic curve.

Our method relies on the equivalence of the inverse spectral problem to a matrix Riemann–Hilbert problem defined on the hyperelliptic curve and generalizes the so-called nonlinear stationary phase/steepest descent method for Riemann–Hilbert problem deformations to Riemann surfaces.

In April-May 2009 we have made progress for the so-called shock problem where the initial data is asymptotically described by elliptic functions. We have shown that the problem is amenable via the introduction of a so-called "g-function", a transformation that enables us to asymptotically tackle the new matrix Riemann–Hilbert problem. We thus generalize the original g-function idea of [3] to Riemann surfaces (rather than just the complex plane) and we are able to describe a generalized Toda shock phenomenon (a dispersive shock studied years earlier by Venakides, Deift, Oba and myself).

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Bernard Helffer

In addition to my activity of organizer, this three months period has been a period of high scientific activity and has also permitted to help my students for finishing their PHD (N. Raymond, J. Martinet) or their Master Thesis (J. Royo-Letellier). In various ways, ESI gives facilities for their stay in Vienna.

At the level of research, I have had many discussions with almost all the participants to the program. This does not lead necessarily to the writing of a paper but their names appear in the acknowledgements of some of the papers mentioned below. In particular, I would like to mention B. Davies, M. Levitin, R. Frank, P. Freitas, F. Hérau, A. Laptev, N. Mangoubi, N. Lerner, Polterovic, K. Pravda-Starov. The list of references correspond to papers which have been partially or completely done at the ESI.

I can classify this research in various directions :

- **Minimal partitions**
  With Thomas Hoffmann-Ostenhof and Susanna Terracini, we have achieved [1] and also made significative progress on [9]. Helped by discussions with M. Levitin, P. Freitas and J. Tidblom, I have written with Thomas Hoffamann-Ostenhof [5] a short note on the comparison between two important notions of minimal partitions. An important program of analysis of minimal partitions through numerical experiments has also been developed with Virginie Bonnaillie-Noel [4]. I gave a survey talk at the first conference on the program (published in an extensive version in [3])

- **Schrödinger with magnetic field**
  My student N. Raymond has obtained during his stay important results for the $(3D)$-case (see ESI preprint 2154, to appear in Asymptotic Analysis) (with Neumann boundary). On my side, I have mainly collaborated with Y. Kordyukov [10] on the $(2D)$ case and we have two other papers in preparation. Connected with one question appearing in this analysis, I have written with M. Persson [7] a proof of a conjecture on the spectral properties of a family of anharmonic oscillators.

- **Superconductivity**
  Although related with the previous subject but more oriented to non-linear analysis, I have continued with S. Fournais the two-years program of writing a book on the spectral methods in superconductivity [6]. I am happy to announce that the book is in press and will appear very soon.

- **Non self-adjoint problems**
  As one knows, this was one important point in the program. I have strongly benefitted of

the visiting colleagues in particular B. Davies and F. Hérau and also of a Post-Doc W. Bordeaux-Montrieux (supported by Feichtinger's group at Vienna University). This leads to the achievment of [2] and to the survey paper [8]. One paper in collaboration with J. Sjöstrand was written after this trimester on the same subject.

References

[1] B. Helffer, T. Hoffmann-Ostenhof and S. Terracini. *On spectral minimal partitions : the case of the sphere.* ESI Preprint 2128. Around the Research of Vladimir Maz'ya III, International Math. Series, Springer, Vol. 13, p. 153-178 (2010).

[2] Y. Almog, B. Helffer and X. Pan. *Superconductivity near the normal state under the action of electric currents and induced magnetic fields in* $\mathbb{R}^2$. Submitted.

[3] B. Helffer. *On spectral problems related to a time dependent model in superconductivity with electric current.* ESI preprint 2192 and submitted to Actes du colloque d'Evian 2009.

[4] V. Bonnaillie-Noel and B. Helffer. *Numerical analysis of nodal sets for eigenvalues of Aharonov-Bohm Hamiltonians on the square and application to minimal partitions.* ESI Preprint 2193 and submitted.

[5] B. Helffer and T. Hoffmann-Ostenhof. *Remarks on two notions of spectral minimal partitions.* ESI preprint 2194 and to appear in Adv. Math. Sci. Appl. (2010).

[6] S. Fournais and B. Helffer. *Spectral Methods in Surface Superconductivity.* Book to appear at Birkhäuser, in the series Progress in Non-Linear PDE.

[7] B. Helffer and M. Persson. *Spectral properties of higher order anharmonic oscillators.* ESI preprint 2197 and Journal of Mathematical Sciences, New York Springer Vol. 165, No. 1, February 2010, p. 110-126.

[8] B. Helffer. *On spectral minimal partitions: a survey.* To appear in Milan Journal of Mathematics (2010).

[9] B. Helffer, T. Hoffmann-Ostenhof and S. Terracini. *Nodal minimal partitions in dimension 3.* In preparation.

[10] B. Helffer and Y. Kordyukov. *Semi-classical spectral asymptotics for a two-dimensional magnetic Schödinger operator : the case of discrete wells.* ESI preprint. Submitted.

Seminars and colloquia outside of conferences

2009 01 07, C. Goldstein: “Herbrand’s number theory: the anti-heroic side of modern mathematics”
2009 01 08, D. Fenster, Bill Cable, Dan Rudary: “To the frontier: E. H. Moore, Leonard Dickson and Oswald Veblen”
2009 01 08, F. Brechenmacher: “A history of the universality of matrices in mathematics: algebraic practices, networks, and cultural issues (1850 - 1939)”
2009 01 08, J. Barrow-Green: “The dramatic episode of Sundman”
2009 01 08, M. Epple: “One or many modernisms in mathematics? Some considerations (post Mehrtens and Gray) on links between mathematics and culture ca. 1900”
2009 01 09, B. Schirmeier: “Publications in the History of Mathematics during the Weimar Republic. A change not only in quantity but also in topics?”
2009 01 09, L. Rodríguez Hernández: “Frigyes Riesz and the concept of space in modern mathematics”
2009 01 09, M. Schneider: “The conceptual exploration of band spectra with group theoretic methods”
2009 01 09, N. Schappacher: “Political Space Curves - reflections on the centennial fate of a mathematical“fact””
2009 01 11, N. Hauser: “Mathematics in Vienna’s ‘Volksbildung’ until 1935”
2009 01 11, R. Chorlay: “‘Im Kleinen - im Grossen’: turn of the century concepts”
2009 01 11, R. Siegmund-Schultze: “Richard von Mises in Vienna and Brünn - mathematical and technical education in the Austro-Hungarian Empire in the first decade of the 20th century”
2009 01 12, J. Leloup: “Analyzing French mathematical research during the interwar period: the examples of geometry and probability theory theses”
2009 01 12, J. Ritter: “Interfering with reception: Ceneral Relativity in 1920s France”
2009 01 12, S. Patterson: “The number-theorist Hermann Minkowski”
2009 01 12, S. Walter: “Hermann Minkowski and theoretical physics in Göttingen”
2009 01 13, G. Savin: “Shimura correspondence for finite groups”
2009 01 13, M. Krishnamurthy: “On the converse theorem for GL(2)”
2009 01 15, V. Sécherre: “l-modular representations of inner forms of GLn over a p-adic field, with l different than p”
2009 01 20, A. Minguez: “l-modular theta correspondence”
2009 01 20, H. Grobner : “Multiplicities of cusp forms for quaternionic hyperbolic spaces”
2009 01 22, J. Cogdell: “On sums of three squares”
2009 01 22, M. Tadic: “unramified unitary duals of classical p-adic groups”
2009 01 26, D. Jiang: “Periods of automorphic forms and related problems”
2009 01 26, D. Prasad: “Symplectic root numbers, central critical L-values, and restriction problems for classical groups”
2009 01 26, M. Vigneras: “Representations of p-adic groups and (0,T)-modules”
2009 01 27, C. Blondel: “Covers and points of reducibility of parabolically induced representations in classical groups”
2009 01 27, E. Lapid: “Model transition”

2009 01 27, G. Harder: “Do exotic mixed Tate motives exist?”
2009 01 27, J. Mahnkopf: “Traces on Hecke algebras and p-adic families of modular forms”
2009 01 28, M. Hanzer: “Rank-one reducibility for the represenations of metaplectic groups via theta correspondence”
2009 01 28, T. Oda: “Explicit formulae for archimedean Whittaker functions on classical groups and related problems”
2009 01 29, A. Minguez: “l-modular representations of inner forms of GL(n) over a non-Archimedian local field”
2009 01 29, G. Henniart: “Cuspidal representations of Swan exponent 1 and the Langlands correspondence”
2009 01 29, M. Tadic: “Automorphic duals of calssical p-adic groups”
2009 01 30, M. Asgari: “Weyl’s law and classical groups”
2009 01 30, S. Stevens: “The supercuspidal represenations of p-adic classical groups”
2009 01 30, T. Hayata: “Hermite constants of Siegel’s fundamental domain of degree 2”
2009 02 02, A. Raghuram: “Special values of some automorphic L-functions”
2009 02 02, I. Badulescu: “Global Jacquet-Langlands: The archimedean part”
2009 02 02, N. Grbac: “The Langlands-Shahidi method for principal series representations of the metaplectic group”
2009 02 03, C. Jantzen: “Discrete series for p-adic SO(2n) and restrictions of representations of O(2n)”
2009 02 03, C. Waldner: “The cohomology of arithmetic subgroups of the exceptional group G_2 and related automorphic representations”
2009 02 03, J. Labesse: “Unitary groups: base change and multiplicity formulas”
2009 02 04, J. Cogdell: “Functoriality for quasisplit classical groups”
2009 02 04, M. Rapoport: “T1(p)-level structures and Hecke algebra isomophisms”
2009 02 05, A. Moy: “A construction of elements in the Bernstein center”
2009 02 05, E. Lapid: “Some aspects of Arthur’s non-invariant trace formula”
2009 02 05, F. Shahidi: “A new look at some functionals appearing in automorphic forms”
2009 02 10, S. Spallone: “Residues of Intertwining Operators for SO(6) as Character Identities”
2009 02 10, V. Heiermann: “Intertwining operators and affine Hecke algebras for some classical p-adic reductive groups”
2009 02 12, S. Patterson: “Weyl multiple Dirichlet series and Gauss sums”
2009 02 12, T. Finis: “On the cohomology of diescrete subgroups of $SL(2,C)$”
2009 02 17, C. Bushnell: “Explicit Jacquet-Langlands correspondence”
2009 02 18, D. Adamovic: “Triplet vertex superalgebras and their representation categories”
2009 02 18, M. Primc: “Monomial bases and fermionic formulas for $\widehat{\mathfrak{sl}_2}$-modules and beyond”
2009 02 19, C. Moeglin: “Image of intertwining operators and residues of Eisenstein series”
2009 02 19, P. Schneider: “The finite generation problem for the (ϕ,Γ)-functor”
2009 02 19, R. Haag: “Blossoming of Mathematical Physics in the second half of the last Century. Personal memories by Rudolf Haag”
2009 03 02, D. Manchon: “Connected Hopf algebras and renormalization, I”
2009 03 02, F. Brown: “Periods, polylogarithms and Feynman Integrals, I”
2009 03 03, D. Manchon: “Connected Hopf algebras and renormalization, II”
2009 03 03, F. Brown: “Periods, polylogarithms and Feynman Integrals, II”
2009 03 03, K. Yeats: “Dyson-Schwinger equations, I”
2009 03 04, D. Manchon: “Connected Hopf algebras and renormalization, III”
2009 03 04, F. Brown: “Periods, polylogarithms and Feynman Integrals, III”
2009 03 04, K. Yeats: “Dyson-Schwinger equations, II”
2009 03 05, S. Paycha: “Renormalised multiple sums and integrals with constraints: application to multiple zeta values and Feynman type integrals, I”
2009 03 05, S. Ramdorai: “Introduction to motives, I”
2009 03 05, S. Ramdorai: “Introduction to motives, II”

2009 03 06, F. Brown: “Periods, polylogarithms and Feynman Integrals, IV”
2009 03 06, S. Ramdorai: “Introduction to motives, III”
2009 03 06, S. Ramdorai: “Introduction to motives, IV”
2009 03 09, D. Manchon: “Connected Hopf algebras and renormalization, IV”
2009 03 09, H. Gangl: “Coproduct and dimension formulas for double zetas and beyond”
2009 03 09, K. Yeats: “Dyson-Schwinger equations, III”
2009 03 09, O. Schnetz: “Results in y^4-theory”
2009 03 09, S. Paycha: “Renormalised multiple sums and integrals with constraints: application to multiple zeta values and Feynman type integrals, II”
2009 03 10, K. Yeats: “Dyson-Schwinger equations, IV”
2009 03 10, M. Laca: “Equilibrium and Symmetries from Number Theory, I”
2009 03 10, S. Paycha: “Renormalised multiple sums and integrals with constraints: application to multiple zeta values and feynman type integrals, III”
2009 03 11, A. Carey: “The local index formula in noncommutative geometry, I”
2009 03 11, A. Levin: “On the way to the elliptic multiple polylogs”
2009 03 11, L. Kadanoff: “Making a Splash, Breaking a Neck: The Development of Complexity in Physical Systems”
2009 03 11, M. Laca: “Equilibrium and Symmetries from Number Theory, II”
2009 03 11, S. Paycha: “Renormalised multiple sums and integrals with constraints: application to multiple zeta values and Feynman type integrals, IV”
2009 03 12, A. Carey: “The local index formula in noncommutative geometry, II”
2009 03 12, M. Laca: “Equilibrium and Symmetries from Number Theory, III”
2009 03 12, S. Rosenberg: “Index Theorems in Riemannian and Noncommutative Geometry, I”
2009 03 13, D. Broadhurst: “Summing an infinite series of perturbative polylogarithms”
2009 03 13, M. Laca: “Equilibrium and Symmetries from Number Theory, IV”
2009 03 13, S. Rosenberg: “Index Theorems in Riemannian and Noncommutative Geometry, II”
2009 03 16, J. Plazas: “From Artin Motives to Endomotives”
2009 03 16, L. Nyssen: “Test vectors for trilinear forms”
2009 03 16, M. Laca University: “Phase transition on the Toeplitz algebra of the affine semigroup over the natural numbers”
2009 03 16, M. Ouedraogo: “The multiplicative anomlay for regularised determinants”
2009 03 17, H. Grosse: “Renormalizable Noncommutative Quantum Field Theory”
2009 03 17, R. Nest: “Applications of triangulated categories in operator algebras”
2009 03 17, R. Wulkenhaar: “Non-compact spectral triples with finite volume”
2009 03 18, N. Yui: “K3 surfaces with non-symplectic group actions, and their modularity”
2009 03 18, P. Freund: “Diffractive Vector Meson Photoproduction from Dual String Theory”
2009 03 18, S. Kondo: “Two higher Chow groups of a scheme over a finite field”
2009 03 18, S. Rosenberg: “Chern-Simons classes on loop spaces”
2009 03 19, C. Bergbauer: “Remarks on renormalization in position space”
2009 03 19, G. Baditoiu: “Lax pair equations and Feynman diagrams”
2009 03 19, L. Boutet de Monvel: “Asymptotic equivariant trace and index”
2009 03 20, C. Neira: “Traces on pseudo-differential operators of negative order and related determinants”
2009 03 20, M. Schlichenmaier: “Almost-graded central extensions of Lax operator algebras”
2009 03 20, M. Szczesny: “Feynman graphs and Hall algebars”
2009 03 24, K. Medynets: “Bratteli diagrams for aperiodic homeomorphisms of a Cantor set”
2009 03 25, D. Blaschke: “Constructing renormalizable models for gauge fields in non-commutative space”
2009 04 01, V. Rivasseau: “Graph polynomials”
2009 04 06, A. Carey: “Spectral flow and invariants of Cuntz-Krieger systems”
2009 04 07, S. Paycha: “The index as a noncommutative residue I”
2009 04 08, R. Lu: “Loop spaces, multiple zeta values and the gamma function”
2009 04 08, S. Paycha: “The index as a noncommutative residue”

2009 04 09, D. Manchon: “planar trees and hypertrees”
2009 04 09, Y. Neretin: “beta (zeta) function of Bruhat-Tits buildings”
2009 04 14, A. Maloney: “The Sum over Geometries in Three Dimensions”
2009 04 14, A. Strominger: “Chiral Gravity”
2009 04 14, C. Meusbburger: “Cosmological measurements, time, and ovservables in (2+1)-gravity”
2009 04 14, M. Henneaux: “Conserved charges in gravitation theory: the Hamiltonian approach”
2009 04 15, A. Waldron: “Weyl Invariance and the Origins of Mass”
2009 04 15, J. Zanelli: “0-Branes in 2+1 gravity”
2009 04 15, M. Gaberdiel: “Extremal conformal field theories and pure gravity on AdS3”
2009 04 15, O. Hohm: “Massive gravity in three dimensions”
2009 04 16, E. Bergshoeff: “Gauging Supergravity in Three Dimensions”
2009 04 16, R. Troncoso: “On the effects of relaxing the asymptotics of gravity in three dimensions”
2009 04 16, S. Carlip: “Chiral topologically massive gravity and the B-F Bound”
2009 04 16, S. Detournay: “Warped AdS3 in string theory”
2009 04 17, G. Compere: “Asymptotic symmetries and central charges in 3d gravity”
2009 04 17, G. Giribet: “Duality between non-rational conformal field theories: some application to three-dimensional gravity in AdS3”
2009 04 17, R. Jackiw: “4 - 3 dimensional reduction of the Weyl tensor and Einstein-Weyl Theory”
2009 04 17, W. Song: “The Perturbative Spectrum in Chiral Gravity”
2009 04 20, D. Lowe: “Black hole complementarity in AdS3”
2009 04 20, M. Banados: “Bigravity and cosmology”
2009 04 20, T. Hartman: “The Kerr/CFT Correspondence: Holography for real-world Black Holes”
2009 04 20, X. Yin: “From 3D Gravity Partition Function to the CFT”
2009 04 21, D. Klemm: “3d gravity with torsion and AdS/CFT”
2009 04 21, D. Vassilevich: “Hunting Chern-Simons in graphene”
2009 04 21, I. Sachs: “Quasi normal modes and stability of the BTZ black hole in topologically massive gravity”
2009 04 21, M. Beiglböck: “Sumset Phenomena”
2009 04 21, O. Hohm: “Massive gravity in three dimensions”
2009 04 22, J. Gegenberg: “3D Gravity from 2D Ricci Flow”
2009 04 22, M. Becker: “Chiral Supergravity”
2009 04 22, M. Porrati: “Canonical Quantization of 3D Pure Gravity and Universal Theichmueller Space”
2009 04 22, S. de Haro: “Dual Gravitons in AdS4/CFT3 and the Holographic Cotton Tensor”
2009 04 23, B. Schroers: “Non-commutative structures and the Galilean limit in 3d quantum gravity”
2009 04 23, D. Anninos: “Warped anti-de Sitter Space in topologically massive gravity”
2009 04 23, D. Fursaev: “Quantum Entanglement and Gravity”
2009 04 23, G. Kunstatter: “Polymer Quantization of the BTZ Black Hole”
2009 04 23, K. Medynets: “Classification of dynamical systems of a Cantor set”
2009 04 30, A. Nogueira: “Lattice orbit distribution on $\mathbf{R}2$”
2009 05 07, D. Szasz: “Energy Transfer and Joint Diffusion”
2009 05 11, E. Harrell: “Trace identities for spectra of Schrödinger operators and semiclassically sharp inequalities for eigenvalues.”
2009 05 11, M. van den Berg: “Minimization of Dirichlet eigenvalues with geometric constraints”
2009 05 12, L. Erdös: “Eigenvalue repulsion for Wigner random matrices.”
2009 05 12, N. Nadirashvili: “Isoperimetric problems for the first eigenvalue.”
2009 05 12, R. Banuelos: “Trace asymptotics for stable hetat semigroups”
2009 05 13, A. El Soufi: “Eigenvalues of the Laplace-Beltrami operator on manifolds”
2009 05 13, R. Shterenberg: “Asymptotic expansion of the integrated desity of states of the two-dimensional periodic Schrödinger operator.”
2009 05 13, Y. Colin de Verdière: “An inverse semi-classical problem motivated by passive imaging in seismology.”

2009 05 14, F. Truc: “Confinig quantum particles with a purely magnetic field.”
2009 05 14, N. Raymond: “Upper bound for the lowest eigenvalue of the Neumann Laplacian with variable magnetic field.”
2009 05 14, S. Fournais: “Superconductivity near the second critical field.”
2009 05 14, Y. Kordyukov: “Semiclassical spectral asymptotics for a Schrödinger operator with hypersurface magnetic wells.”
2009 05 15, D. Mangoubi: “The Volume of a Local Nodal Domain.”
2009 05 15, H. Siedentop: “The Müller functional: asymptotic behaviour of the groundstate energy.”
2009 05 15, I. Herbst: “Analyticity properties of solutions to the Navier-Stokes equations in R^3.”
2009 05 15, J. Solovej: “Atoms with self-generated magnetic fields.”
2009 05 18, A. Girouard: “Isoperimetric ratio, spectrum of hypersurfaces and Steklov spectrum.”
2009 05 18, D. Jakobson: “Estimates from below: spectral function, remainder in Weyl’s law and resonances.”
2009 05 18, G. Teschl: “Spectral theory for perturbed Krein Laplacians in non-smooth domains.”
2009 05 18, M. Levitin: “A class of non-selfadjoint PT-symmetric periodic problems with real spetra.”
2009 05 19, J. Holt: “A Generalization of the Simon-Spencer Theorem.”
2009 05 19, J. Polterovich: “Dynamical features and average growth of the spectral function.”
2009 05 19, O. Safronov: “Absolutely continuous spectrum of Schrödinger operators with no bound states.”
2009 05 19, T. Ostergaard Sorensen: “Regularity properties of atomic and molecular eigenfunctions and their associated densities.”
2009 05 20, B. Nazaret: “Entropies, diffusion equations and functional inequalities.”
2009 05 20, L. Hermi: “A Class of New Inequalities for the Eigenvalues of the Laplacian.”
2009 05 20, R. Benguria: “Zeros of the Fourier Transform of the characteristic function of a domain and Dirichlet eigenvalues.”
2009 05 28, E. Harrell: “Optimization functionals on convex domains”
2009 06 01, G. Sewell: “Stable pure nonequilibrium phases of reservoir driven systems”
2009 06 01, H. Narnhofer: “Time evolution in the thermodynamic limit”
2009 06 02, C. Jaekel: “Remarks on non-equilibrium states for interacting boson fields”
2009 06 02, W. Wreszinski: “Approach to equilibrium for a class of random quantum models of infinite range”
2009 06 04, N. Rougerie: “Extreme rotation regimes for a Bose-Einstein condensate”
2009 06 04, P. Freitas: “On a Nonlocal Heat Flow preserving L2-Norms”
2009 06 04, T. Krajewski: “Power series of non linear operators, effective actions and some cominatorial illustrations”
2009 06 05, T. Weidl: “On the existence of infinitely many trapped modes in elastic plates”
2009 06 08, G. Sewell: “Statistical mechanics of relativistic moving bodies”
2009 06 15, F. Schlutzenberg: “Homogeneously Suslin sets in mice with Woodin cardinals”
2009 06 15, J. Krueger: “The Weak Reflection Principle Versus the Reflection Principle”
2009 06 15, K. Thompson: “Nonexistence of universal models at the successors of singular strong limit cardinals”
2009 06 15, L. Soukup: “On properties of families of sets”
2009 06 15, M. Viale: “Some questions on the models of MM”
2009 06 15, S. Fuchino: “Fodor-type reflection principle and its ‘mathematical’ characterizations”
2009 06 15, T. Johnstone: “Substituting Supercompactness by Strong Unfoldability”
2009 06 16, A. Apter: “Indestructible strong compactness but not supercompactness”
2009 06 16, D. Aspero: “A reflection principle compatible with the continuum large (1)”
2009 06 16, D. Ikegami: “Real Blackwell Determinacy”
2009 06 16, D. Sinapova: “Exploring Singular Cardinal Combinatorics”
2009 06 16, J. Brendle: “Cardinal invariants of analytic quotients”
2009 06 16, M. Mota: “A reflection principle compatible with the continuum large (2)”

2009 06 16, P. Larson: “Universally measurable sets in generic extensions”
2009 06 16, V. Torres: “Rado’s Conjecture, Saturation of the nonstationary ideal on ω_1, and two cardinal diamonds”
2009 06 17, B. Löwe: “Eventually Different Forcing at the Second Level of the Projective Hierarchy”
2009 06 17, J. Hamkins: “General relations of the set-theoretic universe to its forcing extensions and grounds”
2009 06 17, S. Jackson: “New partition results from AD”
2009 06 18, A. Rinot: “Diamond on successors of singulars”
2009 06 18, H. Mildenberger: “Proper translation”
2009 06 18, J. Pawlikowski: “Playing with countable support iteration”
2009 06 18, M. Foreman: “Inner models for huge cardinals and Strong Chang’s Conjecture”
2009 06 18, M. Sabok: “On forcing with σ -ideals of closed sets”
2009 06 18, N. Dobrinen: “Tukey degrees of ultrafilters”
2009 06 18, T. Ishiu: “A precipitous club guessing ideal on ω_1”
2009 06 18, T. Yorioka: “CCC without random reals”
2009 06 19, B. Koenig: “Different ways to produce non-special ω_2 -Aronszajntrees”
2009 06 19, I. Farah: “Nonseparable UHF algebras”
2009 06 19, J. Monk: “Towers in Boolean algebras”
2009 06 19, M. Stanley: “The Largest Cardinal and the Inner Model Hypothesis”
2009 06 19, P. Schlicht: “Thin equivalence relations in scaled pointclasses”
2009 06 19, R. Schindler: “Bounded forcing axioms and reflection”
2009 06 19, V. Dimonte: “Non-proper elementary embeddings beyond $L(V_{\lambda+1})$”
2009 06 19, V. Gitman: “Ramsey-like cardinals”
2009 06 22, A. Andretta: “Some descriptive set theory related to the Lebesgue density theorem”
2009 06 22, J. Lopez-Abad: “Generic constructions of Banach spaces”
2009 06 22, M. Hrusak: “Katetov order on Borel ideals”
2009 06 22, M. Zelený: “Games and σ-porosity”
2009 06 22, P. Dodos: “Applications of Descriptive Set Theory in the Geometry of Banach spaces”
2009 06 22, R. Camerlo: “Standard universal dendrites as small Polish structures”
2009 06 23, J. Bagaria: “$C^{(n)}$-cardinals”
2009 06 23, J. Melleray: “Metric structures and applications to the theory of topological groups”
2009 06 23, L. Motto Ros: “A universality property for analytic equivalence relations and quasi-orders”
2009 06 23, P. Dodos: “Applications of Descriptive Set Theory in the Geometry of Banach spaces”
2009 06 23, T. Mátrai: “Cofinal types of definable directed orders”
2009 06 23, V. Kanovey: “On definability of some counterexamples in descriptive set theory”
2009 06 24, L. Nguyen Van The: “Structural Ramsey theory and topological dynamics”
2009 06 24, N. Sauer: “On partitions of relational structures”
2009 06 24, P. Dodos: “Applications of Descriptive Set Theory in the Geometry of Banach spaces”
2009 06 25, A. Törnquist: “The lifting problem for the group of measure preserving transformations on the unit interval”
2009 06 25, C. Laflamme: “Partitions and indivisibility Properties of Countable Dimensional Vector Spaces”
2009 06 25, L. Nguyen Van The: “Structural Ramsey theory and topological dynamics”
2009 06 25, S. Coskey: “On dimension and Borel reducibility”
2009 06 25, S. Gao: “The Descriptive Complexity of Free Bernoulli Subflows”
2009 06 25, V. Ferenczi: “Complexity of isomorphism between Banach spaces and inevitable list of Gowers”
2009 06 26, B. Miller: “Forceless, ineffective, powerless proofs of descriptive set-theoretic dichotomy theorems”
2009 06 26, C. Rosendal: “Infinite asymptotic games and an exact Ramsey principle for block sequences”
2009 06 26, G. Hjorth: “Yet another proof of Gaboriau-Popa”

2009 06 26, L. Nguyen Van The: “Structural Ramsey theory and topological dynamics”
2009 06 26, M. Foreman: “Models for Measure Preserving Transformations”
2009 06 26, S. Thomas: “Some Consequences of Martin’s Conjecture”
2009 07 06, B. Davies: “Pencils, spectra and pseudospectra.”
2009 07 06, E. Carlen: “Entropy production and spectral gaps for master equations of Kac type.”
2009 07 07, L. Friedlander: “Heat trace on a polyhedron.”
2009 07 07, N. Dencker: “The Pseudo spectra of Systems of Semiclassical Pseudodifferential Operators.”
2009 07 07, N. Raymond: “Asymptotic Analysis of the Landau-de Gennes Functional.”
2009 07 07, T. Kappeler: “From Toda to KdV (joint work with D. Bambusi, T. Paul)”
2009 07 08, B. Davies: “Spectral Theory for highly non-self-adjoint operators.”
2009 07 08, J. Solovej: “A new method in the study of the thermodynamic limit of charged systems.”
2009 07 08, K. Pravda-Starov: “semiclassical resolvent estimates for non-selfadjoint operators with double characteristics.”
2009 07 08, M. Zworski: “Probabilistic Weyl laws for quantized tori (joint work with T. J. Christiansen).”
2009 07 09, F. Hérau: “Subelliptic estimates for linearized kinetic equations and applications.”
2009 07 09, N. Lerner: “Coherent states methods for hypoelliptic operators.”
2009 07 10, A. Kachmar: “On the Energy of Bound States for Magnetic Schrödinger operators.”
2009 07 10, H. Siedentop: “Stability of relativistic Coulomb Systems.”
2009 07 10, M. Solomyak: “Counting bound states for Schrödinger operators on the lattice.”
2009 07 10, T. Ostergaard-Sorensen: “The relativisitc Scott correction for molecules.”
2009 07 13, A. Kiselev: “Nonlocal maximum principles for fluid dynamics.”
2009 07 13, L. Parnovski: “Recent results on the spectrum of periodic problems for high energies.”
2009 07 13, T. Suslina: “Homogenization of nonstationary periodic equations.”
2009 07 14, A. Sobolev: “Szegö limit theorem for operators with dicontinuous symbols: Widom’s hypotheis.”
2009 07 14, F. Avkhadiev: “Hardy type inequalities.”
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ACM = Advisory Committee Meeting
CAP = Guest of Prof. Cap
CE = Recent Advances in Integrable Systems of Hydrodynamic Type
CPR = Number Theory and Physics
FS = Mathematics at the Turn of the 20th Century: Explorations and Beyond
GJG = Gravity in Three Dimensions
HAF = Catalysis from First Principles
HG = Quanta and Geometry
HLH = Selected Topics in Spectral Theory
HMS = Representation Theory of Reductive Groups - Local and Global Aspects
HSL = The dbar-Neumann Problem: Analysis, Geometry and Potential Theory
JF = Junior Research Fellow
KFG = Set Theory
RA = Classical and Quantum Aspects of Cosmology
SCH = Guest of Prof. Schmidt
SCHW = Guest of Prof. Schwermer
SF = Senior Research Fellow
SFS = Senior Research Fellow Share
THI = Guest of Prof. Thirring
VNW = Entanglement and Correlations in Many-Body Quantum Mechanics
YNG = Guest of Prof. Yngvason

Acin Antonio, ICFO, Barcelona; 10.08.2009 - 14.08.2009, VNW;

Adamovic Drazen, University of Zagreb, Department of Mathematics; 08.02.2009 - 22.02.2009, SFS;

Aermark Lior Alexandra, Stockholm University; 05.07.2009 - 20.07.2009, JF;

Aguado Miguel, Max-Planck-Insitut füer Quantenoptik, Garching; 09.08.2009 - 14.08.2009, VNW;

Aharonov Dorit, Hebrew University of Jerusalem; 04.08.2009 - 09.08.2009, YNG; 09.08.2009 - 14.08.2009, VNW;

Alekseev Vadim, Universität Göttingen, Mathematisches Institut; 01.03.2009 - 13.03.2009, CPR;

Aliste Jose, Universidad de Chile, Santiago; 31.08.2009 - 31.12.2009, JF;

Ambainis Andris, University of Latvia, Riga; 09.08.2009 - 22.08.2009, VNW;

Andersson Mats, Chalmers University of Technology, Gothenburg; 15.11.2009 - 22.11.2009, HSL;

Andretta Alessandro, Universita di Torino; 15.06.2009 - 26.06.2009, KFG;

Anninos Dionysios, Harvard University, Cambridge; 14.04.2009 - 24.04.2009, GJG;

Apter Arthur W., City University of New York, Baruch College, Graduate Center; 14.06.2009 - 20.06.2009, KFG;

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Arnold Stevan J., Oregon State University, Corvallis; 18.07.2009 - 25.07.2009, BJA;

Aschieri Paolo, Universita del Piemonte Orientale, Alessandria; 08.10.2009 - 10.10.2009, HG;

Asgari Mahdi, Oklahoma State University, Stillwater, Department of Mathematics; 25.01.2009 - 07.02.2009, HMS;

Asperó David, ICREA at University of Barcelona, Department of Logic; 15.06.2009 - 27.06.2009, KFG;

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Avkhadiev Farit G., Kazan State University, Theory of Functions and Approximations; 06.07.2009 - 23.07.2009, HLH;

Avron Joseph, Technion, Haifa, Dept. of Physics; 08.08.2009 - 15.08.2009, VNW;

Baditoiu Gabriel, Romanian Academy, Bucharest, Institute of Mathematics; 10.03.2009 - 31.03.2009, CPR;

Badulescu Ioan Alexandru, Université de Montpellier; 25.01.2009 - 21.02.2009, HMS;

Bagaria Joan, University of Barcelona, Departament de Lògica, Hisoria i Filosofia de la Ciència; 21.06.2009 - 28.06.2009, KFG;

Bahns Dorothea, Universität Göttingen; 07.10.2009 - 11.10.2009, HG;

Baier Thomas, Instituto Superior Tecnico, Lisboa; 02.03.2009 - 13.03.2009, CPR;

Balcar Bohuslav, Czech Academy of Sciences, Prague, Mathematical Institute; 21.06.2009 - 27.06.2009, KFG;

Banados Maximo, Oxford Astrophysics ; 18.04.2009 - 25.04.2009, GJG;

Banuelos Rodrigo, Purdue University, West Lafayette ; 08.05.2009 - 16.05.2009, HLH;

Barcza Gergely, MTA-SZFKI, Budapest; 10.08.2009 - 14.08.2009, VNW;

Barkatou Moulay Youssef, Université de Poitiers; 25.10.2009 - 31.10.2009, HSL;

Barrow-Green June, The Open University, Milton Keynes, Faculty of Mathematics, Computing + Technology; 07.01.2009 - 17.01.2009, FS;

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Barton Nicholas, Institute of Science and Technology Austria, Klosterneuburg ; 20.07.2009 - 24.07.2009, BJA;

Bartoszynski Tomek, National Science Foundation, Arlington; 21.06.2009 - 26.06.2009, KFG;

Bauer Bela, ETH Zürich; 09.08.2009 - 15.08.2009, VNW; 30.08.2009 - 11.09.2009, VNW;

Becker Melanie, Texas A & M University; 13.04.2009 - 24.04.2009, GJG;

Benco Lubomir, University of Vienna; 25.05.2009 - 28.05.2009, CAT;

Benguria Rafael, P.Universidad Católica de Chile, Santiago, Facultad de Fisica; 09.05.2009 - 21.05.2009, HLH; 16.07.2009 - 30.07.2009, HLH;

Bennewitz Christer, Lund University; 12.10.2009 - 23.10.2009, CE;

Bergbauer Christoph, Freie Universität Berlin, Institut f. Mathematik II; 01.03.2009 - 31.03.2009, CPR;

Bergmann Birgit, Johann Wolfgang Goethe-Universität, Frankfurt, Historisches Seminar, AG Wissenschaftsgeschichte; 07.01.2009 - 13.01.2009, FS;

Bergshoeff Eric, University of Groningen, Centre for Theoretical Physics; 14.04.2009 - 18.04.2009, GJG;

Berhanu Shif, Temple University, Philadelphia; 25.10.2009 - 31.10.2009, HSL;

Bering Klaus, Masaryk University, Brno, Institute for Theoretical Physics; 16.07.2009 - 29.07.2009, YNG;

Bianchi Emanuela, La Sapienza, Rome; 01.03.2009 - 31.08.2009, JF;

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Bloch Spencer, University of Chicago; 08.03.2009 - 13.03.2009, CPR;

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Carlen Eric, Rutgers University, Piscataway, Mathematics Department; 28.06.2009 - 12.07.2009, HLH;

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Cummings James, CMU, Pittsburgh; 14.06.2009 - 27.06.2009, KFG;

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D'Angelo John P., University of Illinois, Urbana; 25.10.2009 - 31.10.2009, HSL;

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De Assis Adilson Jose, Technical University of Denmark, Lyngby; 25.05.2009 - 28.05.2009, CAT;

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Dencker Nils, Lund University, Department of Mathematics; 06.07.2009 - 15.07.2009, HLH;

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Derridj Makhlouf, Université de Rouen; 25.10.2009 - 31.10.2009, HSL;

Detournay Stephane, KITP-University of California, Santa Barbara; 12.04.2009 - 20.04.2009, GJG;

Diederich Klas, Universität Wuppertal, Fachbereich Mathematik; 16.11.2009 - 07.12.2009, HSL;

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Dobrinen Natasha, University of Denver, Department of Mathematics; 11.06.2009 - 01.07.2009, KFG;

Dodos Panteleimon Ntontos, University of Athens; 21.06.2009 - 27.06.2009, KFG;

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Downes Sean, Texas A&M University, College Station; 15.04.2009 - 24.04.2009, GJG;

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Edigarian Armen, Jagiellonian University, Krakow, Institute of Mathematics; 29.10.2009 - 14.11.2009, HSL;

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Eisert Jens, University of Potsdam; 09.08.2009 - 22.08.2009, VNW;

Eisler Viktor, Niels Bohr Institute, Kopenhagen; 10.08.2009 - 15.08.2009, VNW;

El Soufi Ahmad, Université Francois Rabelais, Tours, Laboratoire de Mathématique et Physique Theorique; 07.05.2009 - 16.05.2009, HLH;

Engliš Miroslav, Academy of Sciences, Prague, Mathematics Institute; 09.12.2009 - 18.12.2009, HSL;

Epple Moritz, Johann Wolfgang Goethe-Universität, Frankfurt, Historisches Seminar; 07.01.2009 - 09.01.2009, FS;

Epstein Inessa, Caltech, Pasadena; 20.06.2009 - 27.06.2009, KFG;

Erdős László, University of Munich, Math. Inst.; 11.05.2009 - 12.05.2009, HLH; 06.07.2009 - 08.07.2009, HLH;

Erhard Julia, Merton College, Oxford, Department of Mathematics; 13.06.2009 - 27.06.2009, KFG;

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Esteban Maria J., Ceremade, Université Paris-Dauphine; 09.07.2009 - 20.07.2009, HLH;

Evangelakis Peter, Harvard University, Cambridge; 22.08.2009 - 05.09.2009, MI;

Evertz Hans Gerd, TU Graz; 09.08.2009 - 14.08.2009, VNW; 20.09.2009 - 24.09.2009, VNW;

Ejov Vladimir, University of South Australia, Mawson Lakes, School of Mathematics and Statistics ; 26.11.2009 - 04.12.2009, HSL;

Farah Ilijas, York University, Toronto; 13.06.2009 - 20.06.2009, KFG;

Fendley Paul, University of Virginia, Charlottesville; 09.08.2009 - 16.08.2009, VNW;

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Fenster Della Dumbaugh, University of Richmond; 03.01.2009 - 10.01.2009, FS;

Ferber Asaf, Tel-Aviv University; 11.06.2009 - 19.06.2009, KFG;

Ferenczi Valentin, Universidade de Sao Paulo, Instituto de Matematica e Estatistica; 19.06.2009 - 27.06.2009, KFG;

Finis Tobias, Heinrich-Heine Universität, Düsseldorf, Mathematisches Institut; 08.02.2009 - 15.02.2009, HMS;

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Fischer Vera, Kurt Gödel Research Center, University of Vienna; 15.06.2009 - 27.06.2009, KFG;

Flašková Jana, Za'padoceska' Univerzita V Plzni, Pilsen; 14.06.2009 - 27.06.2009, KFG;

Fleischhauer Michael, Technische Universität Kaiserslautern, Fachbereich Physik; 10.08.2009 - 14.08.2009, VNW;

Foreman Matthew, University of California, Irvine; 14.06.2009 - 27.06.2009, KFG;

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Forstneric Franc, University of Lubljana; 08.11.2009 - 15.11.2009, HSL; 17.12.2009 - 20.12.2009, HSL;

Fournais Soeren, University of Aarhus; 11.05.2009 - 21.05.2009, HLH; 06.07.2009 - 11.07.2009, HLH;

Franchini Cesare, University of Vienna, Faculty of Physics; 25.05.2009 - 28.05.2009, CAT;

Francsics Gábor, Michigan State University, East Lansing, Department of Mathematics; 16.12.2009 - 23.12.2009, HSL;

Frank Rupert, Princeton University, Department of Mathematics; 05.07.2009 - 25.07.2009, JF;

Freitas Pedro Sinoes Cristina de, Technical University of Lisbon, FMH, Group of Mathematical Physics; 10.05.2009 - 06.06.2009, HLH;

Fremlin David, University of Essex, Colchester; 21.06.2009 - 27.06.2009, KFG;

Frenkel Edward, University of California, Berkeley; 24.04.2009 - 27.04.2009, ACM;

Fryer Roland, Harvard University; 23.08.2009 - 07.09.2009, MI;

Friedlander Leonid, University of Arizona, Tucson, Dept. of Mathematics; 05.07.2009 - 25.07.2009, HLH;

Friedman Shoshana, CUNY Graduate Center, New York; 15.06.2009 - 22.06.2009, KFG;

Friedman Sy-David, University of Vienna, KGRC Vienna; 15.06.2009 - 27.06.2009, KFG;

Fröwis Florian, Universität Innsbruck, Institut für theoretische Physik; 10.08.2009 - 15.08.2009, VNW;

Fu Siqi, Rutgers University, Camden, Department of Mathematic Sciences; 11.12.2009 - 21.12.2009, HSL;

Fuchino Sakae, Chubu University, Aichi, Japan; 12.06.2009 - 20.06.2009, KFG;

Fuchs Martin, Fritz-Haber-Institut, Berlin; 25.05.2009 - 27.05.2009, CAT;

Fursaev Dmitri, Joint Institute for Nuclear Research, Dubna; 17.04.2009 - 25.04.2009, GJG;

Gaberdiel Matthias, ETH Zürich; 14.04.2009 - 19.04.2009, GJG;

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Gansberger Klaus, University of Vienna; 02.11.2009 - 23.12.2009, HSL;

Gao Su, University of North Texas, Denton, Department of Mathematics; 18.06.2009 - 27.06.2009, KFG;

Gauthier Sebastien, Université Lyon 1 - Claude Bernard ; 07.01.2009 - 13.01.2009, FS;

Gawedzki Krzysztof, ENS, Lyon, Laboratoire de Physique; 08.10.2009 - 10.10.2009, HG;

Gerdjikov Vladimir, Institute for Nuclear Research, Sofia; 12.10.2009 - 23.10.2009, CE;

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