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

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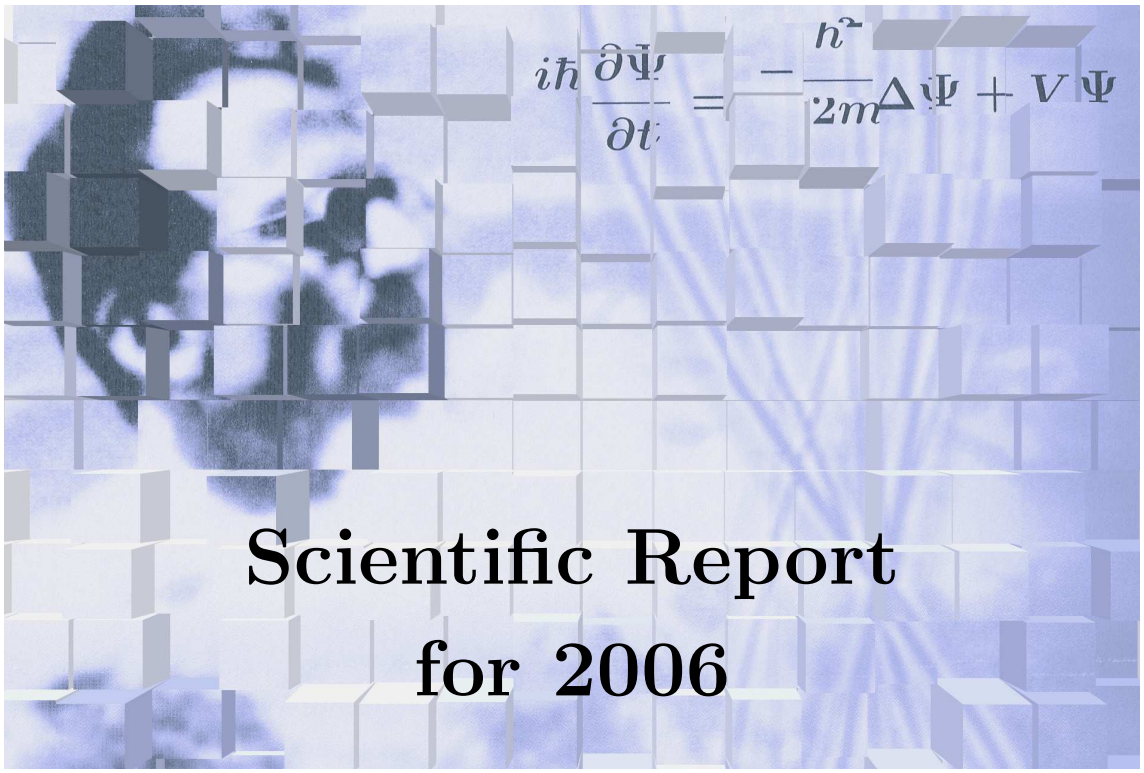

Scientific Report for 2006

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Contents

Preface

The list of subjects covered by the scientific activities of the Erwin Schrödinger Institute in 2006 shows a remarkable variety: the topics range from number theory and arithmetic via a modern take on classical geometry to quantum field theory, complex quantum systems, homological mirror symmetry and optimization. This list is extended further by a series of workshops with an even wider range of topics.

The success of a research institute like the Erwin Schrödinger Institute should, however, not be measured by thematic diversity alone, but by the lasting impact of its programmes on the subjects they cover. The pages of this report provide ample evidence for the scientific benefits of longer research programmes which give scientists the opportunity to collaborate with colleagues over an extended period of time, to acquaint themselves with each others' ideas, and to develop and explore these ideas in a scientifically stimulating atmosphere. Shorter meetings and workshops on specific topics also play an important role in the *exchange* of results, but the longer programmes create the fertile ground for the *birth* of new ideas. The *follow-up workshops* to these major programmes give participants the opportunity to reconvene one or two years later to review and harvest progress resulting from the original programme.

The necessity of these longer programmes and the 'serendipitous' approach to research they permit and encourage is much more difficult to communicate to funding bodies than the need for targeted research and conferences focussed on well-defined and circumscribed topics. As readers of this report will notice, a number of the ESI workshops in 2006 have significant external funding, whereas the large thematic programmes at the ESI generally have to be funded with very little outside support and can be threatened much more easily by political and financial vagaries and, indeed, by inflation.

The ESI Junior Research Fellows (JRF) Programme continued to have a very positive impact on the scientific atmosphere at the Institute through a series of special *Junior Research Fellows Seminars*, through lively discussions and interaction with other post-docs and visitors at the Institute, and through the occasionally very significant research contributions Junior Research Fellows have made. A short overview of the programme (including the list of publications by JRF's) can be found on p. 38f. In 2006 this programme was in the third and final year of its initial funding period, but the ESI has every hope that it will be extended in 2007.

In conjunction with the JRF Programme, and partly with additional funding from external sources, the ESI is now regularly offering *Instructional Workshops* which combine introductory lecture courses by leading international experts with more advanced seminars on active fields of research (cf. p. 30ff.).

As in previous years, the Junior Research Fellows Programme was complemented by the *Senior Research Fellows* (SRF) Programme of the Institute which is funded jointly by the Austrian Ministry for Science and Research, the University of Vienna and the Vienna University of Technology and has the purpose of inviting senior scientists for extended periods of time to offer advanced lecture courses and longer-term scientific interaction with graduate students, post-docs, the local scientific community and the Institute's scientific programmes. The SRF programme is organized by Joachim Schwermer and is described in detail on p. 40ff.

The composition of the *International Scientific Advisory Committee* of the ESI changed

slightly in 2006: Elliott Lieb expressed his wish to retire from the committee. The Institute is extremely grateful to him for many years of valuable advice, suggestions and support, and appointed him as an honorary member of the committee.

There was also a change in the administration of the ESI in 2006. Maria Windhager returned to the ESI office on a part time basis after her maternity leave and Ursula Sagmeister retired after many years of cheerful and competent service for the Institute. As a replacement for Ursula Sagmeister, Irene Alozie was appointed to a part time position in the ESI administration. In spite of these changes the administration — led by Isabella Miedl — continues to work with its customary efficiency and good humour towards our visitors, research fellows and scientific staff of the Institute.

Klaus Schmidt March, 2007
President

General remarks

Management of the Institute

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

International Scientific Advisory Committee

until December 2006:

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Harald Grosse (Vienna)
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Nigel Hitchin (Oxford)
Gerhard Huisken (Potsdam)
Antti Kupiainen (Helsinki)
Elliott Lieb (Princeton)
Michael Struwe (ETH Zürich)

from January 2007:

Edward Frenkel (Berkeley)
Harald Grosse (Vienna)
Giovanni Gallavotti (Roma)
Nigel Hitchin (Oxford)
Gerhard Huisken (Potsdam)
Antti Kupiainen (Helsinki)
Michael Struwe (ETH Zürich)
Elliott Lieb (Princeton), Honorary Member

Budget and visitors: The budget of ESI for 2006 was €957.880,– from the Austrian Federal Ministry for Education, Science and Culture (incl. €94.000,– for the Senior Research Fellows Programme, €95.000,– for the Junior Research Fellows Programme 2006, an additional €100.000,– for "Gender-Mainstreaming" within the Junior Fellows Programme for the years 2005 and 2006) and €22.000,– from the University of Vienna for the Senior Research Fellows Programme. €528.469,65 were spent on scientific activities and €399.239,41 on administration and infrastructure.
The number of scientists visiting the Erwin Schrödinger Institute in 2006 was 557, and the number of preprints was 125.

Scientific Reports

Main Research Programmes

Arithmetic Algebraic Geometry

Organizers: S.S. Kudla (University of Maryland), M. Rapoport (University of Bonn), J. Schwermer (University of Vienna, ESI)

Dates: January 2 - February 18, 2006

Budget: ESI €37.104,91

Preprints contributed: [1811], [1855],[1856], [1857], [1858], [1859], [1860], [1863], [1864], [1865], [1891], [1892], [1894]

Report on the programme

The programme brought together leading experts in arithmetic algebraic geometry and in automorphic forms. The main emphasis was put on the relation between algebraic cycles on Shimura varieties, special values of L-functions and automorphic forms, and p-adic methods.

The classical Ranking-Selberg method which expresses the L-function attached to a pair of modular forms as an integral against an Eisenstein series has played a very prominent role in the study of the arithmetic of special values of L-functions. In fact, the famous conjectures of Deligne concerning the special values of L-functions of motives at their critical points were originally made in response to examples obtained by Zagier using such Rankin-Selberg integrals. Both Hecke's original 'Mellin transform' integrals and the Rankin-Selberg integrals were carried over into the theory of automorphic representations by Jacquet and Langlands. In recent years and in the language of automorphic representations, this classical method has been vastly extended by the work of Rallis, Piatetski-Shapiro, Gelbart, Bump, Ginzburg, Soudry, Jiang and others to provide integral representations and, hence, analytic information about many new families of automorphic L-functions. While the analytic theory of these new Rankin-Selberg integrals has become quite well developed, relatively little work has been done on their arithmetic applications. A main goal of this part of the programme was to stimulate research on such applications by bringing together specialists in the Rankin-Selberg methods and specialists in relevant areas of arithmetic and geometry. Also, the recent surge of activity in the p-adic domain promises to have important applications to this circle of problems. Therefore, quite a number of p-adic specialists were invited to stimulate further interaction between these areas.

Shimura varieties, the varieties whose complex points arise as (unions of) quotients of bounded symmetric domains by arithmetic groups, are among the most interesting of all algebraic varieties, and are deeply tied to the theory of automorphic forms. Many, including the classical modular and Shimura curves and the Siegel modular varieties, are moduli spaces for families of abelian varieties. The structure and arithmetic of such varieties has been the subject of very extensive research. One main focus of this part of the programme was the study

of algebraic cycles on Shimura varieties, particularly on those 'special cycles' which arise as sub-Shimura varieties. For example, one would like to calculate the heights of such cycles with respect to natural metrized line bundles. One would like to understand the classes of such cycles in (i) cohomology (topological) (ii) in the Chow ring (algebraic) (iii) in the arithmetic Chow ring (arithmetic) of a Shimura variety as well as the relation of such classes to special values of certain L-functions. Although the systematic study of such cycles is still in its early stages, there have been a number of recent developments (generalized Arakelov theory, modular generating functions, Lefschetz type restriction theorems) which suggest that important new progress is now possible. A goal of this part of the programme was to stimulate collaborative research by gathering specialists currently working in this area.

In the following we describe some of the main subjects of the programme.

1. Generating series from special cycles on Shimura varieties

Generating series arising from symmetric subspaces of symmetric spaces were introduced a long time ago by Kudla and Millson who studied their modularity in several papers. The case where complex structures are involved, was taken up only recently. Kudla proved for the Shimura variety associated to $SO(n,2)$ that the corresponding generating series is equal to a special value of a Siegel-Eisenstein series. Tsuzuki has considered a similar problem for the Shimura variety associated to $SU(n,1)$. As an application, he obtains a lower bound on the dimension of the second degree cuspidal cohomology of these varieties.

In his Annals paper on this subject, Kudla introduced an arithmetic analogue of these generating series for Shimura curves. He proved, at least partially, that this generating series is the special value of the derivative of a Siegel-Eisenstein series. This result was completed recently in joint work of Kudla, Rapoport and Yang. However, in their result they have to assume, that no level structure is involved. Kudla and Rapoport obtained new results in the case of level structure $\Gamma_0(p^n)$, generalizing to this case Gross's theory of quasi-canonical divisors.

Other generating series are obtained by taking the cup product with the canonical bundle. Kühn reported on his joint results with Bruinier and Burgos on such generating series in the case of a Shimura variety of Hilbert-Blumenthal type, and related developments. During the programme, Kudla and Kühn made progress on similar generating series which should eventually lead to a new proof of the formula for the self-intersection number of the canonical bundle over a Shimura curve, a result in the monograph of Kudla, Rapoport, and Yang, which is proved there only in a rather indirect way.

2. Langlands functoriality and L-functions

Here the emphasis was on the L-function approach to lifting automorphic representation from a classical group to the general linear group, via converse theorems. Jiang and Soudry reported on their joint results on lifting cusp forms on an odd special orthogonal group. In order to use effectively the L-function machinery, control over its functional equation is essential. Cogdell reported on the potential use of the 'stability of gamma factors' for lifting problems. Soudry reported on his joint work with Rallis on the stability of local gamma factors, arising from the doubling method.

In a somewhat different direction, Shahidi reported on how to use Langlands functoriality and the theory of special values of L-functions for GL_n to infer information on special values of automorphic L-functions on classical groups. Here an interesting interaction with Mahnkopf from the University of Vienna, a specialist for GL_n, took place.

Henniart gave an overview of recent progress in the local Langlands correspondence obtained by him and Badulescu.

Blasius explained a conjecture on the size of the image of Galois representations coming from automorphic forms, and explained cases where it seems hopeful to make progress on it. He also reported on density results related to this conjecture.

Wintenberger presented his spectacular proof, joint with C. Khare, of Serre's modularity conjecture: any 2-dimensional odd irreducible representation of the Galois group $Gal(\overline{\mathbb{Q}}/\mathbb{Q})$ with values in a finite field comes from a modular form.

3. Interaction with p-adic methods

Colmez reported on his work on a p-adic Langlands correspondence for $GL_2(\mathbb{Q}_p)$ which relates analytic representations of this group with values in a p-adic field, and p-adic Galois representations of $Gal(\overline{\mathbb{Q}}_p/\mathbb{Q}_p)$. Especially striking for the automorphic participants in this programme, and cause for lively discussions, was the fact that the established correspondence is *functorial*, in contrast to the much better known classical case.

Nekovar gave a report in his work on Euler systems of CM points on Shimura curves, and related it to the theory of eigen curves by using his theory of Selmer complexes. Cornut has applied some of these results to prove jointly with Vatsal the conjecture of Mazur on the non-triviality of the p-adic anticyclotomic Euler system attached to CM points on Shimura curves over totally real number fields. This also yields new cases of the Birch-Swinnerton-Dyer conjecture.

Bertolini reported on his joint work with Darmon. In this work a p-adic analogue of the theory of Heegner points on Shimura curves plays a prominent role. Since the classical Heegner points are the prime example of special cycles on Shimura varieties, this analogy served as a catalyst for discussions between people in both fields. Also, the approach by Bertolini and Darmon to special values of complex L-functions via Stark-Heegner points served as a point of contact with the specialists in special values of automorphic L-functions.

In another direction, Skinner and Urban gave an extended exposition of their work on the Iwasawa main conjecture for $GL(2)$. Their approach is through a lower bound on the Eisenstein ideal for the group $U(2,2)$, which in turn is obtained through a study of the corresponding Shimura variety. Here there were lively discussions with Harder, who compared the Betti and the deRham versions of Eisenstein cohomology classes on various Shimura varieties. Gotsbacher gave an account of his extended calculations of these cohomology classes in the case of Shimura varieties of orthogonal type. These results form part of his thesis written under the direction of Schwermer at the University of Vienna.

4. Residues of Eisenstein series

The discrete spectrum of the space of square-integrable automorphic forms of a reductive algebraic group G defined over an algebraic number field k splits very naturally into the cuspidal spectrum and the residual spectrum. The latter one is generated by residues of Eisenstein series attached to cuspidal automorphic forms on Levi subgroups of proper parabolic k-subgroups of G. Thus, one way to determine the structure of the residual spectrum is to analyze the analytic behaviour of the constant terms of the Eisenstein series involved. The other one goes over so called period integrals. On one side, the former question is closely related to the analytic behaviour of ratios of automorphic L-functions attached to the given cuspidal data, on the other hand, to a thorough understanding of local intertwining operators, for example, at ramified places. There are some results regarding these problems for split k-groups G and Eisenstein series attached to cuspidal automorphic forms on Levi subgroups in minimal or maximal k-parabolic groups but otherwise these questions are open. Dihua Jiang, Soudry, Cogdell, Harder and Schwermer discussed various approaches to determine the location of poles of Eisenstein series in other cases. There are interesting relations with the construction of so called CAP-representations. This is well understood, for example, for the symplectic group of degree 2. Applications of this result in arithmetic questions were discussed by Cogdell and Schwermer. This relation for other groups, even of small k-rank, deserves further study. Works of Schwermer include applications of the investigations of residues of Eisenstein series to the existence of certain cohomology classes for arithmetic groups which are of interest in number theory.

5. Trace formulas and analytic approaches

Lapid gave a series of lectures on periods of automorphic forms, in the sense of Jacquet. In particular, he highlighted the analytic difficulties in dealing with the relative trace formula and how to overcome them, with applications to periods of cusp forms on GL_n along anisotropic unitary groups contained in them. He also explained some applications to conjectures of Sarnak on the L^∞-norm of automorphic forms. Analytic methods are also used by Luo in his work on equidistribution problems of Hecke eigenforms on the Siegel threefold and on Hilbert-Blumenthal varieties.

6. Arakelov geometry

A series of lectures was given by Bost and Künnemann on their theory of extension groups of hermitian vector bundles on arithmetic varieties. The theory presented has fascinating relations to diophantine equations and also to the geometry of numbers. The theory of Bost and Künnemann is located in the 'pure' Arakelov theory, whereas the theory of Kudla and Rapoport, even though it uses concepts and methods from Arakelov theory, has a thrust which is different. It was generally felt that the interaction of these different points of view holds a promise for the future.

Invited scientists: Tobias Berger, Massimo Bertolini, Don Blasius, Jean-Benoit Bost, Jose Ignacio Burgos, James Cogdell, Pierre Colmez, Christophe Cornut, Gerald Gotsbacher, Harald Grobner, Günter Harder, Michael Harris, Takahiro Hayata, Guy Henniart, Fritz Hoermann, Benjamin Howard, Dihua Jiang, Juerg Kramer, Stephen S. Kudla, Ulf Kuehn, Klaus Künnemann, Erez Lapid, Joachim Mahnkopf, Wenzhi Luo, Tomonori Moriyama, Werner Mueller, Stefan Müller-Stach, Jan Nekovar, Michael Rapoport, Jürgen Rohlfs, Freydoon Shahidi, Christopher Skinner, David Soudry, Masao Tsuzuki, Eric Urban, Ognjen Vukadin, Christoph Waldner, Jean-Pierre Wintenberger

Diophantine Approximation and Heights

Organizers: D.W. Masser (University of Basel), H.P. Schlickewei (University of Marburg), W.M. Schmidt (University of Colorado)

Dates: February 27 - May 12, 2006

Budget: ESI €8.175,–, University of Vienna €25.500,–

Preprints contributed: [1848], [1853]

Report on the programme

Preamble. In our original Proposal of December 2003, we mentioned four topics that we considered to be the main themes of the Workshop. These were the following:

(A) The Subspace Theorem and its ramifications.

(B) Heights of subvarieties of group varieties.

(C) The complete solution of Catalan's equation.

(D) Linear independence of zeta values.

All this turned out to be too ambitious for the parameters of 2006, and so we had to scale things down. We decided to omit (C) and (D) altogether; in fact the topic (C) has not developed so well as the others, although the topic (D) remains a very active area of research, especially by the Russian school. We also decided to reduce some aspects of (A) and (B).

1. Description. We begin our report with a description of the topics (A) and (B).

(A) The deep Subspace Theorem plays a key role in modern number theory and its applications. Dating back to Schmidt's 1972 pioneer work for number fields, it has been extended by Evertse and Schlickewei in 2002 to involve the field of all algebraic numbers. With Schmidt this has led to elegant uniform upper bounds for the number of solutions of linear equations

$$a_1x_1 + \cdots + a_nx_n = 1$$

in subgroups of finite rank in fields of zero characteristic. Such equations are interesting not only to number theorists; for example they occur somewhat unexpectedly in the study of mixing for dynamical systems of algebraic origin, and here in positive characteristic too (most recently in a 2004 paper of Masser).

The Subspace Theorem also has applications to linear recurrence sequences, and the results of Schmidt in 1999, 2000 are outstanding recent examples, being the first quantitative versions of the famous Mahler-Lech Theorem (1935, 1954).

There are also recent applications (Locher, Schlickewei), generalizing results of Schmidt and Wirsing (1969,1970), which limit the approximation of a given algebraic number α by algebraic numbers β of fixed degree. Such limitation results can further be applied to conclude the finiteness of the solution sets of certain diophantine equations. Here it may not be out of context to mention recent asymptotic counting results for such β (Masser-Vaaler).

Incidentally a recent result of Roy implies that in some special cases α can have unexpectedly good approximations by β. This was discovered in the context of applications (Laurent, Waldschmidt) to transcendence theory and algebraic independence theory (the latter was the subject of a major breakthrough in 1996 by Nesterenko for π and e^π).

Equally incidentally, these questions are especially interesting in positive characteristic, where the best possible exponent of approximation is related to Kodaira-Spencer deformation theory (Thakur).

Over the last few years the Subspace Theorem has been applied in an essentially different way to diophantine equations and recurrence sequences by Corvaja and Zannier; this has led to deep new results on equations in several variables as well as the solution of classical Pisot-type conjectures on recurrence sequences.

In fact Corvaja and Zannier have developed along similar lines a startling variety of other applications, for example to Mahler's method in transcendence theory, the confirmation of an old conjecture of Győry-Sarközy-Stewart on greatest prime factors, the construction of new universal Hilbert sets, and so on.

Central to all modern formulations of the Subspace Theorem is the concept of height.

(B) The theory of heights of subvarieties of group varieties, following earlier work of Bombieri, Schlickewei, Schmidt, Wirsing, and Zannier, has been extensively developed in the last few years by Amoroso, David, and Philippon. It has connexions with deep problems in algebraic geometry (Bogomolov, Zhang) as well as the concrete classical 1933 Lehmer Problem. It vastly generalizes the well-known Mahler measure (which incidentally also occurs in the study of entropy in dynamical systems of algebraic origin, at least in the codimension one case - what happens in higher codimension remains unclear. Its values are closely and mysteriously related to the values of L-functions, for example of elliptic curves).

The main aim of the theory is to establish lower bounds for such heights, and nowadays, like the upper bounds associated with the Subspace Theorem, these lower bounds are remarkably

uniform in character. In fact the bounds are directly used in applications of modern versions of the Subspace Theorem, so this similarity is hardly surprising. The bounds have all sorts of other applications, such as dependence problems on group varieties or on algebraic curves or surfaces lying in such varieties (works of Bombieri, Masser and Zannier from 1999 onwards, and of Viada and Rémond). Some of these problems are connected with well-known works of Schinzel on irreducibility of polynomials.

Another approach to such lower bounds is through Galois equidistribution results like those of Ullmo (1996), Zhang (1998), or Bilu (1997). This latter work can also be used to obtain sharp bounds, and even better, in certain dependence problems (Cohen-Zannier 2000).

2. Talks with comments. Below we list, in chronological order, the talks presented at the Workshop, accompanied by brief comments of our own. We also classify into topics, using (O) for material other than (A) or (B). Usually this (O) is related in various ways to diophantine approximation.

Umberto Zannier (*Scuola Normale di Pisa*): "Some results on integral points for $\mathbf{P}_2$ minus a variety in the function field case". In a splendid opening talk he presented his latest results in the direction of Vojta's Conjectures on rational points. Small but very significant advances on very difficult problems. Makes essential and typically ingenious use of (A).

Harm Derksen (*University of Michigan*): "A Skolem-Mahler-Lech Theorem in positive characteristic". A very original work, using techniques from automata theory, which is closely connected with D.M.'s paper of 2004 on linear equations and mixing problems for dynamical systems of algebraic origin. Will eventually have connexions also with (B).

Nicolas Ratazzi (*University of Paris VI*): "Zero estimates and Seshadri constants". Gives some technical results needed to establish lower bounds for (B), taking better into account some distribution properties (O).

Philipp Habegger (*University of Basel*): "Multiplicative dependence and isolation". Gives some very sharp upper bounds for (B), together with much finer properties.

Patrice Philippon (*CNRS*): "Uniform bounds for the number of rational points on certain curves". Results in the direction of a very difficult Conjecture of Mazur; the proofs use considerations from (B).

Jeffrey Thunder (*Northern Illinois University*): "Counting subspaces of given height defined over a function field". Again (B) in positive characteristic.

Francesco Amoroso (*University of Caen*): "Lower bounds for the height and size of the class group". Classified under (B), but in fact related to heights of single algebraic numbers, not points.

Gaël Rémond (*University of Grenoble*): "On the number of rational points on curves". A very interesting and remarkably uniform counting result; again the proofs use considerations from (B).

Sinnou David (*University of Paris VI*): "Heights on elliptic curves". Results from (B) which are used in the work with Philippon above. Also mentioned recent work on heights and discrepancy.

Noriko Hirata-Kohno (*Nihon University*): "Number of solutions to unit equations in two variables". Looks like it could be (A), but in fact uses hypergeometric method (O) to count very efficiently solutions of the *abc* equation.

Corentin Pontreau (*University of Caen*): "Small points on surfaces". Well inside the topic (B), and a substantial simplification of the general work in arbitrary dimension.

Wadim Zudilin (*Moscow University*): "Effective lower bounds for $\|((N+1)/N)^k\|$". Again the hypergeometric method (O).

Jeffrey Vaaler (*University of Texas*): "An *ABC* inequality for Mahler's measure". An interesting extension of classical *abc* methods for polynomials, in which their heights (B) are estimated rather than their degrees.

Tarlok Shorey (*Tata Institute*): "Prime divisors of products in arithmetic progression". Results, elementary and otherwise, on greatest prime factors of certain products (O).

Yann Bugeaud (*University of Strasbourg*): "Transcendental continued fractions". Develops his very interesting work with Adamczewski, using methods from (A) to prove the transcendence of some natural continued fractions.

Jan-Hendrik Evertse (*University of Leiden*): "Pairs of binary forms with given resultants". Develops his earlier deep work using techniques from (A).

Kálmán György (*University of Debrecen*): "Polynomial powers and binomial Thue equations". Surveyed recent results on diophantine equations whose proofs use a variety of different techniques, including the modular method (O).

Pietro Corvaja (*University of Udine*): "Greatest prime factor of Markov pairs and integral points on surfaces". Gave some variations on themes from Zannier's talk, with applications to numbers arising from elementary number theory (A).

Aurélien Galateau (*University of Paris VI*): "The Bogomolov problem on a product of elliptic curves". Results from (B) again in the two-dimensional case.

Daniel Bertrand (*University of Paris VI*): "Some remarks on the functional Schanuel conjecture". Discussed several aspects of this famous conjecture, including the recent work of Zilber; this also has connexions with recent work of Bombieri, Zannier and myself (O).

Yuri Nesterenko (*Moscow State University*): "Algebraic independence in p-adic domain". Some new results of Lindemann-Weierstrass type, which bring the p-adic theory almost up the level of the classical complex theory (O).

Damien Roy (*University of Ottawa*): "Simultaneous rational approximations to a real number, its square and its cube". Due to unforeseen circumstances D.M. was unable to attend this talk. But it almost certainly develops his exciting work on the unexpected exponents (O).

Michel Laurent (*CNRS*): "Exponents of diophantine approximation in dimension two". Due to unforeseen circumstances D.M. was unable to attend this talk (O).

Michel Waldschmidt (*University of Paris VI*): "Survey of some recent results on the complexity of expansions of algebraic numbers". Due to unforeseen circumstances D.M. was unable to attend this talk. But it probably includes material from the talk of Bugeaud (A).

Cameron Stewart (*University of Waterloo*): "On heights of multiplicatively dependent numbers". The title and the first part of this talk suggested topic (B); but it later turned out to be more about simultaneous diophantine equations (O).

Yu Kunrui (*Hong Kong University of Science and Technology*): "Bounds for the solutions of S-unit equations and decomposable form equations". Described his recent work with György about *abc* equations over number fields (O).

Andrzej Schinzel (*Institute of Mathematics PAN*): "On the reduced length of a polynomial". Due to unforeseen circumstances D.M. was unable to attend this talk, but he heard a similar talk given by the speaker later in Luminy. The reduced length has a harmless-looking definition, but still no-one knows any algorithm to calculate it, even for cubic polynomials (O).

Dinesh Thakur (*University of Arizona*): "Automata and applications to transcendence". Another side of automata theory, and the applications are in positive characteristic (O).

Robert Tijdeman (*University of Leiden*): "Approximation of euclidean distances on $\mathbf{Z}^2$". This was an interesting talk about how using simple ideas from diophantine approximation can reduce the time taken in calculating distances in two dimensions (O).

Günter Lettl (*University of Graz*), "On a conjecture of E. Thomas". Presented some recent work on this conjecture, to the effect that all the solutions of members of a family of diophantine equations very often arise from a family of solutions (O).

Heinrich Massold (*ETH Zürich*): "Approximation of transcendental points on projective varieties". Due to unforeseen circumstances D.M. was unable to attend this talk. From the abstract it concerns diophantine approximation and applications to algebraic independence (O).

Gregory Margulis (*Yale University*): "Oppenheim conjecture and related problems". This was a fitting climax to the Workshop; a beautiful exposition of older and recent work on diophantine approximation using the ergodic methods pioneered by the speaker (O).

3. Remarks. We believe that the Workshop served its purpose, at least to the extent of making clear the continued importance of the topics (A) and (B).

Apart from the use of (A) in Evertse's talk and the more unconventional use of (A) in the talks of Corvaja and Zannier, we saw in the talks of Bugeaud and Waldschmidt how another way of using (A) to establish transcendence has developed. This latter area continues to be very actively explored.

And many talks testified to the usefulness of (B). Noteworthy were the talks of Philippon, David, and Rémond, on subjects not obviously connected with heights. The talks of Pontreau, Galateau, and Habegger show that this topic has taken root also among the younger generation. The talks of Amoroso, Vaaler, Stewart, Yu, and Schinzel made it clear the concepts like height underlie many different areas of number theory.

As for the topic (O), the talks of Derksen, Thunder, and Thakur concerned positive characteristic. And classical diophantine approximation was kept very much alive in the talks of Hirata-Kohno, Zudilin, Nesterenko, Roy, Laurent, Tijdeman, Massold, and of course Margulis.

Of course the talks themselves just served as a focus for other activities. We saw on more than one occasion the very long blackboards almost fully covered, and the discussion and collaboration between participants led to significant progress on several challenging arithmetical problems.

Invited Scientists: Francesco Amoroso, Christoph Baxa, Vasili Bernik, Daniel Bertrand, Yann Bugeaud, Maria Carrizosa, Pietro Corvaja, Sinnou David, Emmanuel Delsinne, Harm Derksen, Michael Drmota, Jan-Hendrik Evertse, Clemens Fuchs, Aurelien Galateau, Kalman Gyory, Philipp-Erich Habegger, Noriko Hirata-Kohno, Michel Laurent, Guenter Lettl, Christine Liebendoerfer, Gregory Margulis, David Masser, Heinrich Massold, Yuri Nesterenko, Patrice Philippon, Corentin Pontreau, Nicolas Ratazzi, Purusottam Rath, Gael Remond, Damien Roy, Andrej Schinzel, Hans-Peter Schlickewei, Wolfgang Schmidt, Johannes Schoissengeier, Fritz Schweiger, T.N. Shorey, Chris Sinclair, Cameron Stewart, Dinesh Thakur, Robert Tichy, Rob Tijdeman, Jeffrey Thunder, Michel Waldschmidt, Martin Widmer, Jeff Vaaler, Carlo Viola, Kunrui Yu, Umberto Zannier, Wadim Zudilin

Rigidity and Flexibility

Organizers: V. Alexandrov (Sobolev Institute, Novosibirsk), I. Sabitov (Moscow State University), H. Stachel (Vienna University of Technology)

Dates: April 23 - May 6, 2006

Budget: ESI €17.890,64

Preprints contributed: [1791], [1796], [1868], [1869]

Report on the programme

This ESI Programme brought together highly qualified researchers working on different aspects of rigidity and flexibility. Such a convene is of high importance as the solution of problems in this field requires different techniques ranging from classical differential geometry to geometry 'in the large', convex geometry, algebraic geometry, geometric analysis, kinematics, combinatorics, scientific computations and algorithmics. This was the first international meeting dedicated to rigidity and flexibility.

The programme was aimed at the study of various flexible and rigid structures such as flexible polyhedra and frameworks, polyhedral herissons and virtual polytopes, smooth herissons and smooth surfaces. To recall, a polyhedron is said to be flexible if its spatial form can be changed analytically with respect to a parameter while its intrinsic metric remains unaltered. A few outstanding rather recent results were: R. Connelly constructed a piecewise linear flexible embedding of the 2-sphere into the Euclidean 3-space E^3, a flexing sphere. R. Alexander proved that every flexible polyhedron in E^3 preserves its total mean curvature during the flex. And I. Sabitov proved the famous Bellows Conjecture stating that for every flexible polyhedron in E^3 the volume remains constant during the flex. This surprising result is based on a generalized Heron formula: The squared volume of any triangulated sphere-like polyhedron is root of a polynomial with coefficients depending on the edge lengths only.

The main topics of the programme were:

- Finite deformation of polyhedra
- Infinite bendings of polyhedra and surfaces
- Bricard's flexible octahedra
- Combinatorial methods for characterizing rigidity
- Hedgehog theory and virtual polyhedra
- On A.D. Alexandrov's theorem on the realization of Euclidean metrics
- Applications of rigidity

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

1. **Finite deformation of polyhedra:**
   The meeting started with an overview on flexible polyhedra and an outlook to open problems (R. Connelly). J. Schlenker reported about how to use hyperbolic geometry for obtaining rigidity theorems on polyhedra in the Euclidean space. Up to now only a small number of flexible polyhedra is known. Each of these examples can be realized by a real-world model. A. Milka presented a series of almost flexible examples thus initiating a discussion on what flexibility means in our physical world. Another form of weakening flexibility is that of regarding polyhedra with boundary. H. Maehara gave an example of such a polyhedron which can be reversed. Bendings of polyhedra with boundary play an important role in discrete differential geometry for discrete integrable systems (T. Hoffmann). As a limiting case of a polyhedron with boundary, A. Dolbilin presented A. Tarasov's sophisticated solution of V.I. Arnold's problem: How to fold a rectangular sheet of paper into a flat polygon with larger perimeter.

2. **Infinite bendings of polyhedra and surfaces:**
   L. Velimirovic gave a historical overview of the theory of infinitesimal bendings of surfaces and discussed toroidal surfaces with polygonal meridian. I. Sabitov showed that all flat tori are bendable in the spherical space S^3 while these surfaces are unbendable in the Euclidean space. T. Hoffmann demonstrated the application of infinitesimal flexibility of polyhedra in discrete differential geometry. The fundamental question of how to define higher order rigidity or flexibility was addressed by H. Stachel.

3. **Combinatorial methods for characterizing rigidity:**
   The rigidity of generic 3D graphs is of high importance for studying the flexibility of molecules. The Molecular Conjecture, posed in 1984 by T-S. Tay and W. Whiteley, indicates that determining whether a molecular graph is rigid (or more generally, computing the rank of its rigidity matroid) may be tractable by combinatorial methods. Interesting results in this direction were presented by B. Jackson, T. Jordan, B. Servatius and Z. Szabadka. These methods consist mainly in decompositions of the graph into rigidity blocks. O. Shai addressed the equivalences between rigidity or flexibility of structures and particular properties of graphs. A. Recski presented polynomial algorithms for checking the rigidity of tensegrity frameworks.

4. **Bricard's flexible octahedra:**
   These most famous flexible polyhedra date back to Roul Bricard (1896). They are the basis for most of the known flexible polyhedra, in particular for Connelly's flexing sphere and for Steffen's flexible polyhedron. There are three types to distinguish, one with a planar symmetry, one with line symmetry and one totally asymmetric. Nevertheless, V. Alexandrov proved that also this third type has local symmetries at each vertex, and that all

types fulfil the strong Bellows Conjecture stating the scissor congruence of any two flexes. P. Penning gave a summary on different kinematic properties of the relative motions showing up at these octahedra. And S. Mikhalev presented 7 independent conditions on the edge lengths of any octahedron for obtaining one of Bricard type 3.

5. **Hedgehog theory and virtual polyhedra:**
   There are attempts to weaken the condition of convexity in the classical Cauchy rigidity theorem. Recent examples are herissons (= hedgehogs) which can be seen as Minkowski differences of convex bodies. In an overview Y. Martinez-Maure explained the genesis of some of the main results on herissons and listed a series of open problems in this field. At the same time he proposed new tools for studying these open problems. G. Panina presented a mini-course on hyperbolic virtual polytopes with emphasis on A.D. Alexandrov's problem and on closed saddle polytopal surfaces.

6. **On A.D. Alexandrov's theorem:**
   The theorem under consideration states that any convex polyhedral metric on the 2-sphere can be realized as the boundary of a convex polytope in E^3. I. Izmestiev provided an algorithmic solution for this polyhedron. This theorem was also addressed in G. Panina's lecture series on hyperbolic virtual polytopes. F. Fillastre presented an analogous statement for a compact surface S of genus ≥ 2.

7. **Applications of rigidity:**
   The applications of rigidity theory in chemistry and in discrete differential geometry have already been mentioned above. Beyond these topics, there are applications, e.g., at circle packings on the sphere (T. Tarnai). Here rigidity characterizes optimal packings, and the Danzerian degree corresponds to the degree of freedom of the assembly. Regarding applications in mechanics, T. Tarnai showed that different principles concerning stiffness or stability of self-stress at bar-and-joint assemblies can be unified using the Hellinger-Reissner principle. W. Whiteley focussed on relations between rigidity theory and projective geometry.

Invited scientists: Victor Alexandrov, Robert Connelly, Nikolaj Dolbilin, François Fillastre, Tim Hoffmann, Manfred Husty, Ivan Izmestiev, Bill Jackson, Tibor Jordan, Natalia Kopteva, Hiroshi Maehara, Yves Martinez-Maure, Sergej Mikhalev, Anatoliy Milka, Georg Nawratil, Gajane Panina, Paul Penning, András Recski, Otto Röschel, Idzhad Sabitov, Jean-Marc Schlenker, Bernd Schultze, Brigitte Servatius, Offer Shai, Hellmuth Stachel, Dragutin Svrtan, Zoltan Szabadka, Tibor Tarnai, Johannes Wallner, Dominik Walter, Gunter Weiss, Walter Whiteley, Ljubica Velimirović

Gerbes, Groupoids and Quantum Field Theory

Organizers: P. Aschieri (Università del Piemonte Orientale, Alessandria), H. Grosse (University of Vienna), B. Jurco (University of Munich), J. Mickelsson (KTH Stockholm), P. Xu (Pennsylvania State University)

Dates: May 8 - July 31, 2006

Budget: ESI €62.005,20

Preprints contributed: [1808], [1813], [1818], [1828], [1829], [1837], [1838], [1839], [1840], [1847], [1851], [1861], [1870], [1872], [1888]

Report on the programme

This ESI programme attracted all together 105 visitors. From May 9 to May 13 the 10th Workshop on Algebraic Geometry and Physics was organized together with Ugo Bruzzo from SISSA (Trieste). Among the 50 participants of this Workshop 33 were financed by their own Institute respectively by SISSA.
Alan Carey joined the programme but was fully sponsored as a Senior Research Fellow of the Clay Institute [see p. 45].
The participants benefited from the advanced graduate lecture course on "K-Theory applied to physics", given by Varghese Mathai, a Senior Research Fellow at the ESI at the time.

The programme of the first Workshop included minicourses by B. Fantechi and P. Xu, where the algebraic stack and the groupoid perspectives on gerbe theory were presented. These served as basis for a set of 20 more technical talks. Moreover T. Pantev gave a series of beautiful talks on the geometric Langlands duality, while N. Hitchin lectured on generalized complex geometry. Physical applications of this last topic where also presented during the workshop. As usual in this series of workshops, the programme included both more foundational and mathematical talks together with contributions more oriented to physical applications, notably topological quantum field theory and conformal field theory.

During the second week of July a Workshop on Generalized Geometries, coorganized with P. Michor took place. There, many topics in generalized geometry where covered including stacks, generalized complex structures, twisted K-theory, gerbes and deformation theory. Speakers included R. Fernandes, E. Meinrenken, P. Schapira, P. Severa, T. Strobl and B. Tsygan.

During the three months period of the programme there were lively discussions among the participants. The topics investigated can be summarized as:

1. Index theory, Dirac operators, twisted K-theory and D-brane charges
2. Characteristic classes
3. Equivariant twisted K-theory
4. (Nonabelian) Gerbes as bigroupoid bundles and groupoid extensions, higher category theory
5. Simplicial and categorical methods
6. Differential geometry of gerbes
7. Deformation quantization and gerbes
8. Applications of gerbes in supergravity and M-theory
9. String product on loop stacks

1. Index theory, Dirac operators, twisted K-theory and D-brane charges
Progress was made especially in understanding T-duality in string theories on noncommutative space-time and associated D-brane charges, (hep-th/0607020, ESI preprint 1813) which was completed by J. Brodzki, V. Mathai, J. Rosenberg, R. Szabo during their stay at ESI. Further collaborations in this direction included P. Bouwknegt and K. Hannabuss. Related work done at ESI led to the article by J. Evslin and H. Sati on D-brane charges on nonrepresentative cycles (i.e., cycles which are not represented as smooth submanifolds), hep-th/0607045. S. Paycha and J. Mickelsson discussed at ESI topics related to the use of renormalized trace calculus in families index theory of Dirac type operators (math.DG/0607148, ESI preprint 1818).

2. Characteristic classes
A. Carey, J. Mickelsson and B. Wang started a project on twisted K-theory characteristic classes in relation to the torsion classes arising for example in twisted K-theory on compact Lie groups; the tool here is to use secondary characteristic classes produced by Deligne cohomology in case when the twisted cohomology vanishes. They had intense interactions with Franz Kamber and Johan Dupont who gave seminars on the simplicial approach to gerbes and on Deligne cohomology.

3. Equivariant twisted K-theory
Recently the work of Freed, Hopkins and Teleman on the correspondence of the twisted equivariant K-theory of a compact group and its Verlinde ring as well as the explicit construction of this correspondence by J. Mickelsson using the Dirac operator on the corresponding loop group attracted much attention. Related work has been done by A. Alekseev, G. Landweber, E. Meinrenken, and B. Wang and A. Carey who continued their investigations in that direction.

4. Gerbes as bigroupoid bundles and groupoid extensions, higher category theory
The theory of Lie groupoids has undergone rapid development in the last fifteen years. It played a fundamental role in the recent development of Poisson geometry. Considerable attention has been directed at the Poisson sigma model of Schaller, Strobl and Ikeda. Roughly speaking, they generalize usual gauge theories by replacing the gauge group by a Lie groupoid. The Poisson sigma model was employed by Cattaneo and Felder in depth, they showed that the perturbative quantization of this model yields Kontsevich's celebrated star-products. It is known that one way to look at (nonabelian) bundle gerbes is to describe them as groupoid extensions or as (nonabelian) descent data (in the spirit of the original abelian definition by Murray). Another point of view is the one of bigroupoid bundles. This is closer to higher category theory. It also suggests to look at the more general case of the bicategory bundles. The precise relation between bigroupoid bundles and groupoid extension, the corresponding nonabelian cohomology, classifying spaces and toposes and related questions were discussed by a number of participants including P. Aschieri, I. Bakovic, T. Beke, L. Breen, B. Jurco, K. Mackenzie, Z. Skoda, U. Schreiber, D. Roberts. Questions of higher Cech cohomology theory and of the nonabelian parallel surface transport were discussed. Analogously nonabelian bundle 2-gerbes can be described as extensions of bigroupoids or as higher descent data. Both points of view were elaborated along with the notion of a 2-bouquet by I. Bakovic and B. Jurco.

5. Simplicial and categorical methods
Powerful categorical and simplicial methods can be applied to gerbes as well. Bundle 1-gerbes are related to simplicial bundles and homotopy type 2 via crossed modules of groups (or more generally groupoids) and their nerves. This generalizes to the case of bundle 2-gerbes, homotopy type 3 and crossed squares. Participants mentioned before (under point 4) were discussing related questions too. Discussions with Franz Kamber and Johan Dupont were appreciated.

6. Differential geometry of gerbes
Similar to the case of line bundles, a gerbe can be given in terms of local 'transition functions'. However now 'transition functions' are to be replaced by local complex line bundles satisfying cocycle conditions for tensor products over triple overlaps of open sets. A more global point of view is to think of a gerbe as a principal $PU(H)$ bundle. Here $PU(H)$ is the *projective unitary group* in a complex Hilbert space H. In contrast to line bundles, gerbes are generically infinite-dimensional objects; only in the case of a torsion 3-cohomology class one can choose H to be finite-dimensional. Differential geometry of nonabelian (one) gerbes was originally developed by Breen and Messing using synthetic differential geometry. Later it was reinterpreted in terms of traditional differential geometry and also in the language of Lie groupoids and algebroids. Topics discussed by participants included the possible generalization of the Chern-Weyl theory of real characteristic classes using the gerbe connection and possible approaches to the differential geometry of 2-gerbes.

7. Deformation quantization and gerbes
Advances in deformation theory of gerbes came trough discussions of P. Aschieri, I. Bakovic, B. Jurco, J. Mickelsson, P. Schupp, P. Severa, B. Tsygan. In this context a key role is played by noncommutative bundles. In particular deformations of bundles and of the corresponding gauge theories have been investigated by P. Aschieri, F. Bonechi, L. Dabrowski, M. Dimitrijevic, G. Fiore, H. Grosse, B. Jurco, G. Landi, F. Lizzi, V. Mathai, P. Schupp, H. Steinacker and P. Vitale. During the programme the role of Drinfeld twist deformations in constructing noncommutative geometries has been better understood, and many research activities have started (for example on noncommutative Yang-Mills instantons and on quantization of twisted noncommutative classical field theories). A related topic has been the deformation quantization of (co)tangent bundles geometry, and of the theory of gravity.

8. Applications of gerbes to supergravity and M-theory
Discussions among E. Aldrovandi, P. Aschieri, L. Castellani, B. Jurco, J. Kalkkinen, U. Schreiber has brought more evidence that the structure of free differential algebras (that underlies 11 dim. supergravity) is related to that of gerbes. The topological role in M-theory played by the E_8 group (and related to 2-gerbes) has found further evidence in the results of I. Sati hep-th/0608190 (ESI preprint 1841).

9. String product on loop stacks
Loop spaces and especially loop manifolds have been studied extensively for a long time. Recently, many new algebraic structures have been discovered on the homology space of loop manifolds by Chas and Sullivan, which are normally referred to as string topology. The geometric and topological meanings of string topology have become an increasingly interesting subject of study currently. G. Ginot, B. Noohi and P. Xu made significant progress in the study of the singular version of string topology, namely string topology for topological stacks. The relation between the string topology and the Chen-Ruan product was investigated when the stacks are orbifolds.

Invited Scientists: Andrea D'Agnolo, Ettore Aldrovandi, Anton Alekseev, Elena Andreini, Paolo Aschieri, Igor Bakovic, Klaus Bering, Francesco Bonechi, Peter Bouwknegt, Lawrence Breen, Ugo Bruzzo, Ulrich Bunke, Andrei Caldararu, Alan Carey, Leonardo Castellani, Ludwig Dabrowski, Aydin, Demircioglu, Marija Dimitrijevic, Jarah Evslin, Johan Dupont, Barbara Fantechi, Giovanni Felder, Rui Loja Fernandes, Gaetano Fiore, Ale Frabetti, Gregory Ginot, Nikolaj Glazunov, Vassily Gorbounov, Beatriz Grana Otero, Jose Gracia-Bondia, Michele Grassi, Pietro A. Grassi, Harald Grosse, Stephane Guillermou, Keith Hannabuss, Daniel Hernandez, Pedram Hekmati, Nigel Hitchin, Keiichi R. Ito, Michael Joachim, Branislav Jurco, Jussi E. Kalkkinen, Franz Kamber, Boris Khesin, Herbert Kurke, Giovanni Landi, Gregory Landweber, Camille Laurent, Remi Leandre, Fedele Lizzi, John Madore, Yoshiaki Maeda, Kirill Mackenzie, Eckhard Meinrenken, Peter Michor, Jouko Mickelsson, Behrang Noohi, Francesco Noseda, Tony Pantev, Sylvie Paycha, Pietro Polesello, Norbert Poncin, Ashok Raina, Rui Reis, Antonio Ricco, David Roberts, Hartmann Roemer, Jonathan Rosenberg, Vladimir Roubtsov, Hisham Sati, Pierre Shapira, Martin Schlichenmaier, Urs Schreiber, Peter Schupp, Christoph Schweigert, Pavol Severa, Eric Sharpe, Zoran Skoda, Mathieu Stienon, Thomas Strobl, Vesa Tähtinen, Alessandro Tanzini, Alessandro Tomasiello, Emilio Torrente, Boris Tsygan, Jean-Louis Tu, Muhammed Uludag, Bernardo Uribe, Rikkard von Unge, Alessandro Valentino, Mathai Varghese, Patrizia Vitale, Aissa Wade, Konrad Waldorf, Bai-Ling Wang, Simon Willerton, Ping Xu, Maxim Zabzine, Marco Zambon, Alessandro Zampini, Bin Zhang, Youjin Zhang, Xinwen Zhu, George Zoupanos, Roberto Zucchini

Complex Quantum and Classical Systems and Effective Equations

Organizers: E. Carlen (Georgia Institute of Technology), L. Erdős (University of Munich), M. Loss (Georgia Tech School of Mathematics)

Dates: May 15 - August 15, 2006

Budget: ESI €43.074,99

Preprints contributed: [1797], [1812], [1823], [1825], [1831], [1832], [1833], [1844], [1845], [1852], [1867], [1871], [1877], [1878], [1879], [1881], [1887]

Report on the programme

The past few years have seen progress on a number of mathematical problems concerning complex systems with many degrees of freedom such as field theory models and statistical mechanical models. A common goal in many such problems is the derivation of effective equations for a few special degrees of freedom describing physically important collective phenomena. This is the case in both classical problems of kinetic theory, and quantum problems involving Bose condensation, to name just two examples.

As the terminology itself suggests, this topic is not a single well defined field, and the practitioners do not form a single community. However, the premise on which the workshop was organized was that there was significant common ground that the various communities were working, and that it would be productive and beneficial to all involved to bring these communities together for collaboration.

In organizing the workshop we focused on a large group working on problems related to the Boltzmann equation and kinetic theory, and another one that is working on scaling limits for deriving effective equation such as the Gross-Pitaevskii equation, as well as a a large community that works on relativistic many body problems. The goal of this programme was to bring together these various groups with highly developed skills and techniques in the hope that they might have impact on problems across the topics of their immediate interest. While the full success of this endeavour can only emerge over a larger time frame, there are some significant signs of early success which will be reported in what follows, and which are quite promising with regard to longer term impact.

The programme was framed between two workshops, the first in the first week of June and the second in the last week of July. The format was devised to take into account the presence of participants from a wide range of backgrounds. We began each day with consisted of two overview lectures in the morning, by the same speaker, which gave a detailed and broadly accessible introduction to some topic or field in which recent progress had been made, and in the afternoon, this was followed by three shorter lectures, which generally related to the topic introduced in the morning in some fairly direct way. Between the workshops we held a weekly seminar, and there was active discussion and collaboration underway at all times, resulting even in the short period between the workshop and now, in a substantial list of preprints.

We shall now explain in more detail some of the main themes, and some of the progress made. The list of topics below is not complete; a full list can be gleaned from the programmes for the workshops. Here we focus on those topics in which work has already resulted in an ESI preprint, or in which there is reason to expect that such a preprint will be forthcoming.

1. Boltzmann equation

One of the two–part morning lectures was given by Spohn. The lecture and the ensuing discussions provide a perfect example of the synergies and interactions that the workshop was designed to generate. Spohn's lecture concerned a new and surprising direction research on weakly nonlinear wave equations. In a momentum space formulation, the solutions can be understood in terms of colliding modes, thus opening up the possibility of bringing techniques from the Boltzmann equation to bear on these kind of problems. Desvillettes, one of the foremost experts on the Boltzmann equation, expressed great interest in pursuing these kinds of questions. We expect that he will do so successfully, and that in the longer term, significant work will be produced in the Boltzmann equation community as a direct result of this interaction.

Closely related to this is the work of Lukkarinen on the wave propagation in anharmonic lattices with random masses, where the techniques developed by Erdős and Yau are applied to this topic. An important technical advance on the estimate of the so-called crossing diagrams can be found in [1797] of Erdős and Salmhofer.

A perhaps surprising range of interesting phenomena occur in Boltzmann type models where the energy conservation is violated. The application of such kind of theories to granular media was explained by Mouhot in another of the two part morning lectures. The key problems is to establish is separation of time scales and to find the large time profiles. Related problems were also presented by Gamba. Carlen, Gabetta, Regazzini [1871] investigated infinite energy solutions of the spatially homogeneous Boltzmann equation. Recent work had shown that all finite energy solutions approach a Maxwellian equilibrium, though the rate of approach can be arbitrarily slow if the energy distribution has long tails. This work shows that if the energy is actually infinite, there is no limiting distribution, and all the mass runs off to infinity, though again it may do so arbitrarily slowly, depending on the tails of the energy distribution once again. This has consequences for the structure of eternal solutions of the spatially homogeneous Boltzmann equation; all of the non constant examples that are known have infinite energy.

Another important example of a problem in which the separation of scales play a prime role, time scales as well as space scales, is the adiabatic approximation. This was explained by G. Panati and its application to piezoelectricity by Sparber. Further related talks on decoherence and approach to equilibrium were given by Adami respectively Joye. A general framework for quantum statistical models having good hydrodynamic properties was presented by Sewell.

2. Bose gas and Gross-Pitaevskii equation

Schlein gave an overview on the derivation of the time dependent Gross-Pitaevskii equation for interacting Bose gases (jointly with Erdős and Yau [1879]). The result is that the many body Schrödinger evolution of the interacting Bose gas can be approximated by a single particle cubic nonlinear Schrödinger equation in the limit where the scattering length tends to zero and the number of particles to infinity in such a way that the interaction does *not* become weak, but localized. This is the same scaling used in the previous results of Lieb, Seiringer, Yngvason on the derivation of the time independent Gross-Pitaevskii theory for the ground state of the trapped interacting Bose gas. An important recent advance for the nonzero temperature problem can be found in the work of Seiringer [1845]. Dereziński emphasized the study of the joint spectrum of the Hamiltonian the momentum operator, a point of view that is presumably important for a rigorous theory of superfluidity. An interesting problem is the analysis of the Gross-Pitaevskii equation for a Bose condensate in a rotating trap. Correggi gave an overview about the intricacies of rapidly rotating condensates in strongly anharmonic traps.

3. Relativistic many body theory

The status of the problem was nicely summarized in an overview lecture of Séré and the more technical aspects were supplied by a lecture of Hainzl. The main result, which is jointly with Lewin and Solovej, is a solid understanding of the second quantized Dirac equation interacting with external nuclei. The theory, however, is within a Hartree-Fock approximation and without the interaction with the radiation field. The correct vacuum polarization emerges and if one restricts oneself to a fixed charge sector, the Dirac-Fock equations emerge. New phenomena occur if one includes external magnetic fields in the Dirac theory since this allows for the penetration of eigenvalues into the lower continuum, which one relates heuristically to pair creation. Although, this topic has not progressed very far, preliminary steps have been taken in work of Dolbeault, Esteban, Loss, [1812] where the size of such magnetic fields are estimated. In a different vein, Pachutzki reported about high accuracy QED calculations for atoms.

4. Mathematical theory of Non-relativistic Quantum Electrodynamics

An overview talk on 'atomism and quantization' by Fröhlich, one of the initiators of the mathematical theory of QED, provided the background for a number of special talks. Pizzo

presented rigorous asymptotic expansion in the fine structure constant of the ground state energy of hydrogen which is joint work with Bach and Fröhlich. Further, Schlein, talked about the scattering theory below the ionization level (Rayleigh scattering), which is joint work with Fröhlich and Griesemer. Sigal provided an overview of the main mathematical ideas behind much of this work. It is a highly nontrivial renormalization group method that leads to an infrared fixed point of the theory. A taste of this one can get for [1867] which is work of Fröhlich, Griesemer and Sigal. The infrared problem in QED has plagued the community since the creation of the subject. Chen showed in his talk how to construct infrared representation for a charged particle interacting with the radiation field. Two more directions of work have to be mentioned, the one of Zenk, who derived Einstein's law of the Photoelectric effect from non-relativistic QED, [1852] and the one by Loss, Miyao and Spohn on the existence of ground states for moving charged particles interacting with the radiation field. The analogous problem for the Nelson model was explained by A. Panati. Both Miyao and Zenk gave talks in the second workshop. On a more abstract level was the talk of Dereziński on the connections between Bogoliubov automorphisms and strongly continuous one parameter groups on Fock space. Leading further into field theory were the talks of de Bièvre and Jaekel. The former studied the Unruh effect, i.e., the fact that a field theory in an accelerated frame acquires a thermal state. Jaekel explained field quantization in curved space time, using algebraic techniques.

5. Other related topics As emphasized at the outset, this workshop encompassed a wide range of topics, not all of which can be so easily categorized. For example, one of the weekly seminars was given by Rossana Marra, who spoke on kinetic type problems in a phase segregation problem. Here, because of the presence of several phase transitions, the nature of the equilibrium towards which the non equilibrium system should be relaxing is not even clear. While at the ESI, Carvalho, Carlen, Esposito and Marra essentially completed work establishing the nature of the equilibrium in the region critical for "droplet formation" in a physically realistic model that is derived from an actual many body microscopic model. Previous work in this area had only dealt with a phenomenological model involving a Cahn–Hilliard type energy functional. The preprint resulting from this shall soon appear on the ESI server.

Another weekly seminar was given by Bruno Nachtergaele, who presented new results on quantum information theory, and in particular the proof of a conjecture by Narnhofer. This, as other of the weekly seminars, brought the participants into contact with other member of the Viennese scientific community.

We also mention in this framework the talk given by Hans Kosina of the University of Technology, Vienna, who talked on the application of the Wigner function formalism in nano-electronic device simulation. This was followed up with a lecture by Anton Arnold, who also spoke at the first workshop, on open quantum systems in the density matrix formalism. His lecture provided a mathematical development of some of the issues raised in Kosina's lecture, and the two lectures together provided many interesting challenges to the many people at the workshop who are interested in both quantum mechanics and kinetic theory.

In summary, we feel that the programme was quite successful in bringing together people from different communities in a way that has stimulated the production of a number of results already, but more importantly, has led a number of participants to take up new directions of work from which we can expect to see further significant impact in the near future. The same effect would have been difficult to achieve in the framework of a one week conference alone, but instead required the longer term incubation that the three month programme at the ESI made possible.

Invited Scientists: Riccardo Adami, Anton Arnold, Jean Bellissard, Federico Bonetto, Eric Carlen, Maria Carvalho, Thomas Chen, Anna Dall'Acqua, Stephane de Bievre, Jan Dereszinski, Laurent Desvillettes, Jean Dolbeault, Laszlo Erdős, Raffaele Esposito, Maria Esteban, Pierluigi Falco, Felix Finster, Jürg Fröhlich, Ester Gabetta, Irene Gamba, Christian Hainzl, Christian Jaekel, Shi Jin, Alain Joye,

Mathieu Levin, Elliott Lieb, Michael Loss, Jani Lukkarinen, Rossana Marra, Tadahiro Miyao, Sergey Morozov, Clement Mouhot, Bruno Nachtergaele, Krzysztof Pachuki, Annalisa Panati, Gianluca Panati, Federica Pezzotti, Alessandro Pizzo, Slobodan Prvanovic, Eugenio Regazzini, Benjamin Schlein, Robert Seiringer, Eric Sere, Geoffrey Sewell, Heinz Siedentop, Israel Michael Sigal, Herbert Spohn, Cedric Villani, Shih-Hsien Yu, Heribert Zenk

Homological Mirror Symmetry

Organizer: A. Kapustin (CalTech) I, M. Kreuzer (Vienna University of Technology), A. Polishchuk (Boston University), K.-G. Schlesinger (University of Vienna)

Dates: June 12 - June 28, 2006

Budget: ESI €15.006,65

Preprint contributed: [1861]

Report on the programme

In June 2006 ESI hosted a workshop on Homological Mirror Symmetry organized by A. Kapustin (Caltech), M. Kreuzer (University of Technology, Vienna) and K.G. Schlesinger (U Wien). There were 50 participants, about 30 of whom were financially supported by their home institutions that contributed besides the travel expenses also the costs for the complete stay in Vienna.

In total, 36 lectures were held at the workshop. Three participants (plus A. Klemm who delivered an introductory course, see below) gave several lectures each:

- E. Frenkel (2 lectures) on "Sigma models in the infinite volume limit"
- A. Kapustin (3 lectures) on "Gauge theory, mirror symmetry, and the geometric Langlands programme"
- M. Kontsevich (4 lectures) on "Topological quantum field theories and geometry of pre-Frobenius manifolds", "A_∞-categories and their (co)homology theories", and "Mirror symmetry for non-zero c_1".

The lectures of M. Kontsevich draw a large audience (up to 75 listeners). In the first part, he addressed the important question how to pass from topological to cohomological field theory, or in other words, how to justify in a mathematically rigorous way that two approaches to mirror symmetry, one motivated by physics another by mathematics, lead to the same results. In the second part, the cohomology of A_∞-structures - which play a central role in homological mirror symmetry - was discussed. The third part included a sketch of a grand scenario for an extension of homological mirror symmetry beyond Calabi-Yau spaces (with examples focusing on the Fano case). Here, M. Kontsevich sketched an approach to the deformation theory of the Fukaya category that is alternative to the one in a forthcoming book of Fukaya, Oh, Ohta and Ono.

Another highlight of the workshop was the lecture series of A. Kapustin on his recent joint work with E. Witten, entitled "Electric-magnetic duality and the geometric Langlands programme". This work contributes two completely new ingredients to homological mirror symmetry for a special class of sigma models with Hyperkähler targets given by the Hitchin moduli space: Firstly, the work provides a link between homological mirror symmetry (as a property of certain two-dimensional field theories) and S-duality (electric-magnetic duality) of $N = 4$ supersymmetric Yang Mills theory in four dimensions. Secondly, the duality of the geometric Langlands programme is, in this context, a natural consequence of homological mirror symmetry with the Hecke eigensheaves appearing as the A-branes, i.e. the objects of the Fukaya category.

It turns out that the D-module property of the Hecke eigensheaves is a consequence of a delicate property of the Fukaya category: For certain non-generic Calabi-Yau spaces (including the case of the Hitchin moduli space), the space of objects has to be enlarged beyond the classical Lagrangian submanifolds to include coisotropic submanifolds (and in this case a special "canonical coisotropic" one of full dimension).

The further talks focused on recent research results on homological mirror symmetry, bringing together a large portion of the leading researchers of the field.

The workshop was supplemented by a course of four lectures given by A. Klemm on "Topological string theory on Calabi-Yau manifolds". This was an introductory course intended for the students of the Vienna universities and young participants of the programme in order to make the research talks more accessible to them.

Invited Scientists: Devis Abriani, Diliwar Amin, Elena Andreini, Denis Auroux, Seguei Barannikov, Jessica Barrett, Victor Batyrev, Ilka Brunner, Ulrich Bunke, Mattai Cafasso, Yassir Dinar, Edward Frenkel, Kenji Fukaya, Ezra Getzler, Dario Gomez, Vassily Gorbounov, Manfred Herbst, Lutz Hille, Kentaro Hori, Paul Hoja, Daniel Huybrechts, Anton Kapustin, Ludmil Katzarkov, Gabriel Kerr, Albrecht Klemm, Maxim Kontsevich, Bernd Kreussler, Maximilian Kreuzer, Wolfgang Lerche, Ana Lopez-Martin, Yujie Ma, Kishore Marathe, Andreas Recknagel, Paolo Rossi, Daniel Ruiperez, Karl-Georg Schlesinger, Paul Seidel, Eric Sharpe, Zoran Skoda, Yan Soibelman, Duco van Straten, Alexandar Subotic, Szilard Szabo, Matthew Szczesny, Dima Tamarkin, Jean-Luis Tu, Alexandr Usnich, Alexander Velez, Bilin Wang

Global Optimization, Integrating Convexity, Optimization, Logic Programming and Computational Algebraic Geometry

Organizers: I. Bomze (University of Vienna), I. Emiris (University of Athens), A. Neumaier (University of Vienna), L. Wolsey (Université de Louvain)

Dates: October 1 - December 23, 2006

Budget: ESI €17.377,50

Preprint contributed: [1883]

Report on the programme

Global optimization is the task of finding the absolutely best set of admissible conditions to achieve an objective under given constraints, assuming that both are formulated in mathematical terms. A special case is the constraint satisfaction problem, where one just wants to find one or all solutions of a given set of constraints. In terms of applications, global optimization is very interdisciplinary; with respect to methods, the last few years were characterized by increasing cross-fertilization with related subjects.

The programme was designed to bring together key experts from the field of global optimization and the disciplines providing theoretical and algorithmic support for solving global optimization problems: convexity, optimization, logic programming, and computational algebraic geometry. The aim of the programme was to emphasize these connections and to enhance the integration of the various techniques into a unified approach to global optimization, mixed integer nonlinear programming, and constraint satisfaction. The hope is that this will result in improved software for the solution of such problems, with resulting speed-ups (for industrial applications) and increased reliability (for safety-critical applications and computer-assisted proofs).

The emphasis was on algorithmic problems and their theoretical analysis but work on applications to robotics, engineering design, and other fields was also included. During the programme 36 researchers from the United States of America, Japan, Algeria, and 11 European countries visited the ESI and interacted effectively.

A peak of the activities was during and around the GICOLAG workshop (December 4–8). The full programme of the workshop is available at
http://www.mat.univie.ac.at/∼neum/gicolag.html.
Further activities involving scientific collaborations took also place during most of the remaining time; in particular, there were numerous additional lectures. A complete list of the talks given during the programme, together with slides for most of the lectures presented, can be downloaded from the GICOLAG website.

The main topics discussed during the programme were

- Large-scale local optimization
- Mathematically rigorous algorithms for verified computations
- Rigorous global optimization
- Global optimization of differential constraints
- Global quadratic optimization
- Discrete optimization
- Algorithmic algebraic geometry
- Integration frameworks
- Applications

In the following we summarize the highlights within each topic.

1. Large-scale local optimization

The well developed theory of local optimization plays a central role for global optimization; finding a local optimizer is an important step in solving the global problem and succeeds if the starting point is close enough to the global minimizer. In our programme, the scientific exchange in this area concentrated on the study and discussion of methods that work for large problems, with a focus on interior point methods. There were also several talks on this topic (Jarre, Sartenaer, di Serafino).

2. Mathematically rigorous algorithms for verified computations

Most numerical computations are approximate only since most real numbers cannot be represented exactly on the computer. Successful algorithms for traditional tasks like linear programming and less traditional problems like semidefinite optimization need a careful implementation to provide guaranteed results in the presence of rounding errors, usually using techniques from interval analysis.

During the programme there was much discussion of recent breakthroughs that allow one to use some algorithms in a black box fashion and still guarantee correct results by appropriate postprocessing. Based upon rigorous postprocessing work presented by Keil (for linear programming) and Jansson (for semidefinite optimization), good progress was made during the programme for semi-infinite linear programming, where the uncountable number of constraints pose additional difficulties. It is expected that this will lead in the near future to rigorous software for semi-infinite linear programming, which will make many problems of approximation theory rigorously tractable on the computer.

Applications of interval analysis to computer-assisted proofs were discussed in a lecture by Csendes and in informal discussions centering around a polynomial problem by Rump.

3. Rigorous global optimization

Interval analysis is a perfect tool for automatically computing estimates on function values, derivatives, bounds on nonlinearities, thus enabling the rigorous numerical solution of global optimization problems. The successful application requires care, however, to avoid excessive overestimation that characterizes the naive approaches. This poses numerous mathematical problems that were discussed. Work in this direction was presented by Kearfott, Kolev, Lebbah, Neumaier, Rueher, and Rump. The many connections to the other topics of the programmes were investigated, and ways to overcome limitations of the software packages presented in some of the talks were discussed.

4. Global optimization of differential constraints

Differential constraints pose a special challenge in rigorous global optimization, since the numerical solution of differential equations is very difficult to accompany by a rigorous error analysis, and optimization compounds the difficulties. New approaches were discussed, involving work by Adjiman, Ratschan, and Tucker. New theory for relaxations of differential constraints developed during the programme should enable the creation of rigorous global solution of optimal control problems in the near future.

5. Global quadratic optimization

Quadratic optimization problems arise in many applications, either as the next modeling level beyond linear programming, or because of a combinatorial structure which often leads to a natural quadratic formulation. Because of its special structure, special mathematical techniques can be brought to bear on these problems. Work by Dür and Anstreicher pushed the limits forward on what can be achieved in this direction.

6. Discrete optimization

Because the finiteness of combinatorial optimization problems, many discrete problems are globally tractable. The challenge here is to push further away the limits where the combinatorial explosion (worst case exponential work) makes the actual computations infeasible. The known connections with semidefinite programming were further explored by Anstreicher and Bomze, using special problem structure. On the other hand, the sensitivity analysis of discrete problems is more difficult than in the continuous case since the notion of small deformations is absent. Interesting discussions centered around recent work of Hooker, utilizing decision diagrams for discrete sensitivity analysis.

7. Algorithmic algebraic geometry

The approximability of sets of polynomial constraints by convex constraints in a higher-dimensional representation led in the last few years to a flurry of activities relating algebraic techniques involving polynomials and global optimization. Progress in this area was reviewed and many of the possibilities that became visible in this direction were investigated. Even old problems concerning polynomials received new attention, and found improved solutions from a complexity point of view. Lectures by Emiris, Garloff, Mourrain, Tsigaridas, and Winkler contributed to this area.

8. Integration frameworks

An important goal of the programme, and a center of attention was the integration of the various tools and techniques to improve the quality of current global optimization software. Several researchers (Domes, Fourer, Schichl, Vigerske) concentrated on this aspect, and presented integration frameworks on the level of modeling languages, software systems, and graphical user interfaces. In collaboration during the programme, various software systems have been connected to work together, and have been ported to additional platforms.

A notable highlight achieved during the programme was work which showed for the first time how to achieve the nearly rigorous global optimization of large-scale black box problems (where a strict mathematical guarantee is impossible by nature of the data available), based on Stefan Vigerske's branch and cut algorithm LaGO for nonconvex mixed-integer nonlinear programmes.

9. Applications

Apart from its intrinsic mathematical interest, global optimization is important for its relevance in applications. Demanding applications from all sorts of areas pose new mathematical challenges to the field. Mainly three important application areas got the attention of the programme: robotics, uncertainty modeling, and engineering design. Especially in robotics, global optimization methods have already made a significant impact; beautiful lectures by Jaulin and Merlet illustrated this, and at the same time gave rise to more difficult new problems. Uncertainty modeling gives rise to optimization problems tractable by semidefinite programming and global optimization. Engineering design often aims for optimality; example applications were presented by Gay, Markot and Vigerske. Other applications were discussed in lectures by Hochbaum (ranking teams or scientific proposals) and Hooker (decision support).

Invited scientists: Claire Adjiman, Kurt Anstreicher, Immanuel Bomze, Tibor Csendes, Ferenc Domes, Mirjam Duer, Ioannis Emiris, Robert Fourer, Jürgen Garloff, David Gay, Dorit Hochbaum, John Hooker, Christian Jansson, Florian Jarre, Luc Jaulin, Baker Kearfott, Christian Keil, Lubomir Kolev, Yahia Lebbah, Mihaly Markot, Andy McLennan, Jean-Pierre Merlet, Bernard Mourrain, Masakazu Muramatsu, Arnold Neumaier, Stefan Ratschan, Franz Rendl, Michel Rueher, Siegfried Rump, Annick Sartenaar, Hermann Schichl, Elias Tsigaridis, Warwick Tucker, Stefan Vigerske, Franz Winkler, Laurence Wolsey

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 14 - January 21, 2006

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 Institute for Mathematical Physics. The meeting this year centered around questions in Lie theory proper and relations with geometry and harmonic analysis. The proceedings of this meeting will be published as a supplement of the 'Rendiconti Matematici di Palermo'.

Aspects of Spectral Theory

Organizers: M. Baake (University of Bielefeld), W. Kirsch (University of Bochum), K. Schmidt (University of Vienna, ESI)

Dates: January 15 - January 19, 2006

Budget: Entirely financed by the German Research Council

Report on the programme

Since July 2005, the German Research Council (DFG) finances a new Collaborative Research Centre (CRC 701) at the Faculty of Mathematics, Bielefeld University, with the title "Spectral Structure and Topological Methods in Mathematics", see
`http://www.math.uni-bielefeld.de/sfb701/` for details.

This CRC has an interesting thematic overlap with the transregio CRC TR 12 "Symmetries and Universality in Mesoscopic Systems", a joint venture of mathematicians and physicists from the universities of Bochum, Köln, Duisburg-Essen and Warsaw. This CRC, also funded by the DFG, was established in 2003 (see `http://www.sfbtr12.uni-koeln.de/` for details). Both CRCs share several research topics that are also regularly present at the ESI. Topics of common interest include spectral theory of operators, random matrix theory, dynamical systems and spectral structures in combinatorial problems as well as the theory of disordered quantum mechanical systems.

As a joint activity in this direction, a workshop entitled: "Aspects of Spectral Theory" was held at the ESI in Vienna, organized jointly by M. Baake (Bielefeld), W. Kirsch (Bochum) and K. Schmidt (Vienna).

Some 25 scientists came together to discuss and share insight into various spectral structures. They formed 3 groups of approximately equal size, one each from the two CRCs and the third joining in from various places, but with a common interest in spectral theory, augmented by some local participants from Vienna.

Altogether, 14 talks were presented, distributed over 3.5 days, which left enough time for lively and detailed discussions. This way, the special setting of the ESI could be used most

efficiently, in particular its supply of blackboards. Meanwhile, the ESI staff did its best to make it a pleasant and memorable event.

Since the main purpose of this meeting was to bring scientists from different research centres together for initiating new collaborations, there is no isolated research highlight to be reported at this stage. Nevertheless, the mix of talks from random matrix theory, random Schrödinger operators, aperiodic order, spectral structures in lattice theory and mathematical physics showed many striking similarities and potential collaborations.

The meeting was considered a great success by all participants, and we thank the ESI for the opportunity to held it there.

Invited scientists: Michael Baake, Wolf-Juergen Beyn, Michael Demuth, Peter Eichelsbacher, Friedrich Goetze, Uwe Grimm, Werner Kirsch, Gerhard Knieper, Thomas Kriecherbauer, Daniel Lenz, Hajo Leschke, Matthias Loewe, Bernd Metzger, Peter Müller, Christoph Richard, Peter Stollmann, Michael Stolz, Vera Thümmler, Ivan Veselic, Peter Zeiner

Meeting of the EU-Network "Analysis of Large Quantum Systems"

Organizer: J. Yngvason (University of Vienna, ESI)

Dates: March 4 - March 5, 2006

Budget: Entirely financed by the EU

Report on the programme

Meeting of the Post Doctoral Training Network HPRN-CT-2002-00277, financed by the European Union. The network incorporates teams from Munich, Copenhagen, Haifa, Mainz, Paris, Vienna, Warsaw and Zurich. The research focuses on topical problems in quantum mechanics that require a broad spectrum of methods from mathematical analysis for their solution. These include the analysis of selected models of condensed matter physics from meso- to macroscopic scales, the dynamics and stability of infinite dimensional quantum systems, the establishment of effective models as limits of fundamental equations and the study of linear and nonlinear aspects of such models.

The main objective of the workshop was to give the young PostDocs of the network opportunity to present recent results of their research. The programme included also two lectures by senior scientists of the network (Ari Laptev and Bergfinnur Duurhus) and a special review lecture (by Markus Reiher, ETH Zürich) on "The Quantum Chemistry View on Relativistic Many-Particle Physics". The lectures of the PostDocs covered a wide range of topics, from Bose-Einstein Condensates to Quantum Field Theory, with particular emphasis on semi-relativistic models for atoms and the interaction of radiation and matter.

Programme:

Søren Fournais: Current of atoms in the magnetic Thomas-Fermi Regime
Rupert Frank: On Lieb-Thirring inequalities for Schrödinger operators with virtual level
Doris Jakubassa: The HVZ theorem for a pseudorelativistic no-pair operator
Sergej Morozov: Stability of Atoms in the Brown-Ravenhall Model
Markus Reiher: The Quantum Chemistry View on Relativistic Many-Particle Physics
Roch Cassanas: Leading energy of the Brown-Ravenhall model for large atoms
Ari Laptev: Two-dimensional Hardy inequalities
Jean Barbaroux: Quantitative estimates on the enhanced binding for the Pauli-Fierz operator
Jacek Wojtkiewicz: Dimer wave functions as ground states of antiferromagnets
Bergfinnur Duurhus: On the spectral dimension of random graphs
Yan Pautrat: Fluctuation algebra for coupled fermionic systems
Michele Correggi: Fast rotating Bose condensates in the Thomas-Fermi regime

Pawel Zin: A variational approach to the excitation spectrum of a homogenous Bose gas
Anna Lisa Panati: Ground state for the massless Nelson model under binding condition
Lars Jonsson: On the effective dynamics of the pseudo-relativistic Hartree equation
Sylvain Golenia: A new look at Mourre's commutator theory
Marwan Shoufan: Construction of Resonances for Atoms minimally coupled to the quantized Radiation Field
Jens Hoppe: Quantum Riemann Surfaces

Invited scientists: Volker Bach, Sven Bachmann, Jean-Marie Barbaroux, Jean-Bernard Bru, Roch Cassanas, Horia Cornean, Michele Correggi, Anna Dall'Acqua, Jan Dereziński, Bergfinnur Durhuus, Wojciech Dybalski, Maria Esteban, Søren Fournais, Rupert Frank, Sylvain Golenia, Gian Michele Graf, Bernard Helffer, Jens Hoppe, Doris Jakobassa, Lars Jonsson, Hubert Kalf, Antti Knowles, Martin Koenenberg, Ari Laptev, Marco Maceda, Oliver Matte, Jacob Moller, Sergey Morozov, Sourour Negra, Gregorio Ortelli, Annalisa Panati, Yan Pautrat, Gerhard Petrakovits, Alessandro Pizzo, Markus Reiher, Marwan Shoufan, Jan Philip Solovej, Thomas Sorensen, Ian Sorrell, Heinz Siedentop, Erik Skibsted, Rafael Tiedra, Jacek Wojtkiewicz, Semjon Wugalter, Walter Zenk, Pawel Zin

RDSES - Educational Workshop on Discrete Probability

Organizers: V. Kaimanovich (International University, Bremen), K. Schmidt (University of Vienna and ESI), W. Woess (Technische Universität Graz)

Dates: March 12 - March 25, 2006

Budget: ESI €12.540,–, ESF €14.000,–

Report on the programme

This workshop took place at the ESI from March 12–25, 2006. It was organised by Vadim A. Kaimanovich (Bremen), Klaus Schmidt (University of Vienna and ESI) and Wolfgang Woess (University of Technology, Graz), and aimed to attract young people coming from the wide area of discrete probability. There were a total of 53 participants.

The main emphasis of this programme was on what can be called "structural probability". This is a branch of probability theory (currently becoming more and more popular) devoted to the study of qualitative aspects of the behaviour of probabilistic models on spaces endowed with rich additional structures (usually of geometric or algebraic origin) and to relating them with the structural properties of the state spaces. The discrete structures are technically much easier to study, so that the underlying ideas become much more exposed. This is why "discrete probability" was chosen as a framework for 4 educational mini-courses (one week each) presented at the workshop. These courses were given by the world's leading experts and centred around the study of various probabilistic problems related to finite and infinite graphs.

Two courses: Alex Gamburd (Princeton) "Discrete and continuous variations on the expanding theme" and Christophe Pittet (Marseille) "Random walks and isoperimetry in compactly generated groups" were devoted to the interrelation between the probabilistic and geometric aspects of the graph theory. More precisely, they focussed on the influence of the isoperimetric properties of the graphs on the behaviour of the transition probabilities with an emphasis on the passage from large finite to infinite graphs. This topic becomes increasingly important in applications due to the use of random walk algorithms by modern search engines (e.g., the famous Google algorithm).

The relationship between probability and geometry was further deepened in the ensuing courses by Persi Diaconis (Stanford) "Sharp transitions in probability, combinatorics, and statistical mechanics" and Greg Lawler (Cornell) "Random walk problems from statistical physics"

where yet another aspect of discrete probabilistic models, their relationship with the transition models of statistical physics, and in particular the cut-off phenomenon was addressed.

The mini-courses were complemented by a series of lectures from eleven 'senior participants', and by talks from the young attendees on their recent work. The term 'educational' in the title of the workshop motivated all speakers to arrange their talks in a well comprehensible style, which resulted in a remarkably large and interested audience. Additionally, all lectures addressed active fields of research.

In the course of the workshop there was a public lecture of Persi Diaconis on 'Mathematics and Magic Tricks' at math.space, which attracted much public interest.

The complete schedule of the workshop can be found at

`http://www.math.tugraz.at/mathc/esi2006/schedule.html`

The RDSES/ESI Educational Workshop on Discrete Probability was funded jointly by the ESF activity 'Phase Transitions and Fluctuation Phenomena for Random Dynamics in Spatially Extended Systems' and the ESI Junior Research Fellows Programme.

Invited scientists: Gideon Amir, Kathrin Bacher, Cyril Banderier, Alexander Bendikov, Sara Brofferio, Dariusz Buraczewski, Andrea Carpignani, Fabienne Castell, Tullio Ceccherini-Silberstein, Andrea Collevecchio, David Croydon, Ewa Damek, Daniele D'Angeli, Persi Diaconis, Alfredo Donno, Michael Drmota, Alex Gamburd, Lorenz Gilch, Bernhard Gittenberger, Ori Gurel-Gurevich, Ben Hambly, Fumio Hiroshima, Andrzej Hulanicki, Satoshi Ishiwata, Vadim Kaimanovich, Motoko Kotani, Iva Kozakova, Christian Krattenthaler, Markus Kuba, Takashi Kumagai, Steven Lalley, Greg Lawler, Vincent Le Prince, Pierre-Yves Louis, Terry Lyons, Pierre Mathieu, Taku Matsui, Matthias Meiners, Peter Mester, Mariyan Milev, Roman Muchnik, Sebastian Müller, Pietro Muliere, Take Nakama, James Parkinson, Mattia Perrone, Christophe Pittet, Balazs Rath, Clement Rau, Ann-Kathrin Röwer, Anna Rudas, Maura Salvatori, Fabio Scarabotti, Klaus Schmidt, Olivier Siegenthaler, Alexandra Siposova, Florian Sobieczky, Thomas Stoll, Tatsuya Tate, Imre Tamas, Andras Telcs, Elmar Teufl, Michael Thon, Adam Timar, Filippo Tolli, Balint Toth, Roman Urban, Wolfgang Woess, Tomas Vetrik, Roland Zweimüller

Boltzmann's Legacy

Organizers: G. Gallavotti (Università di Roma 1), A. Kupiainen (Helsinki University), W.L. Reiter (ESI), K. Schmidt (University of Vienna, ESI), J. Schwermer (University of Vienna, ESI), J. Yngvason (University of Vienna, ESI)

Dates: June 7 - June 9, 2006

Budget: ESI €9.567,–, University of Vienna €7.000,–

Report on the programme

In commemoration of Ludwig Boltzmann's death on September 5, 1906, during his summer vacations in Duino near Trieste the institute organized an international symposium from Wednesday, June 7 to Friday, June 9 in co-operation with the University of Vienna, the City of Vienna and the Austrian Physical Society. The symposium was supported by the Austrian Federal Ministry for Education, Science and Culture, and the Arcotel Boltzmann Vienna.

The Symposium was dedicated to Boltzmann's lasting legacy in kinetic theory, thermodynamics and statistical mechanics, and to his influence as a philosopher of science. Fifteen prominent scientists covered in their lectures various aspects ranging from a historical perspective to modern applications of Boltzmann's ideas. Among the speakers were five Boltzmann medalists. The Symposium was accompanied by an exhibition on Ludwig Boltzmann, organized by the Österreichische Zentralbibliothek für Physik. Ludwig Boltzmann was one of the greatest

scientists of the 19th century and his work is of fundamental importance not only for modern physics but also in chemistry and biology.

The Symposium was opened by the Rector of the University of Vienna, Professor Georg Winckler and the Dean of the Faculty of Physics, Professor Walter Kutschera.

A public lecture in co-operation with the City of Vienna's prominent "Wiener Vorlesung" was given by Jürgen Renn, Max Planck Institute for the History of Science, Berlin, at the Vienna University of Technology. The title of Renn's lecture was "Boltzmann und das Ende des mechanischen Weltbildes".

A central topic of several of the lectures at the symposium was Boltzmann's statistical interpretation of entropy and the second law of thermodynamics. It became apparent that the far reaching implications of Boltzmann's work can still give rise to conflicting standpoints and the discussions after the lectures were most lively, sometimes even passionate! There were also lectures devoted to intriguing physical and mathematical questions related to nonequilibrium statistical physics and Boltzmann's transport equation as well as recent developments in computational physics that allow a detailed study of nonequilibrium phenomena previously inaccessible to analysis. Further topics included Boltzmann's influence in the life sciences and Boltzmann's philosophy of science.

Most of the lectures delivered, together with additional material, will be published as a special volume of the ESI Lecture Series.

Programme:

E. G. D. Cohen, Rockefeller University, New York: Entropy, probability and dynamics

Nadine de Courtenay, CNRS, Paris. Boltzmann's philosophy of science: a technical adventure

Christoph Dellago, University of Vienna: From hard spheres to soft matter: Boltzmann's legacy for the computational physicist

Michael E. Fisher, University of Maryland: Atoms and ions; Universality, singularity and particularity: lessons from a half-century of statistical physics

Giovanni Gallavotti, Università di Roma 'La Sapienza': Chaoticity as a unifying principle of equilibrium and nonequilibrium statistical mechanics

Oscar E. Lanford III, ETH Zürich: Deriving the Boltzmann equation from microscopic hard-sphere dynamics

Joel L. Lebowitz, Rutgers University: On the Role of Boltzmann's Entropy in the Time Evolution of Macroscopic Systems

Elliott H. Lieb, Princeton University: What if Boltzmann had known about quantum mechanics – and other questions

Donald S. Ornstein, Stanford University: Random or determined?

Jürgen Renn, MPI für Wissenschaftsgeschichte, Berlin: Boltzmann und das Ende des mechanischen Weltbildes

David Ruelle, IHES, Bures-sur-Yvette: Is entropy production local in infinite classical systems?

Peter Schuster, University of Vienna: Boltzmann and evolution - basic questions of biology seen with atomistic glasses

Herbert Spohn, TU München: The Boltzmann transport-equation for weakly nonlinear lattice dynamics

Cédric Villani, École Normale Supérieure de Lyon: Beyond the H-Theorem: Boltzmann's entropy in today's mathematics, from partial differential equations to geometry

Jakob Yngvason, University of Vienna: Boltzmann's legacy from the point of view of a mathematical physicist

Anton Zeilinger, University of Vienna: Boltzmann's legacy from the point of view of an experimentalist

Invited Scientists: E.G.D. Cohen, Nadine de Courtenay, Silvio Dahmen, Christoph Dellago, Kari Eloranta, Michael E. Fisher, Giovanni Gallavotti, Oscar E. Lanford, Joel L. Lebowitz, Elliott H. Lieb, Donald O. Ornstein, Jürgen Renn, David Ruelle, Peter Schuster, Herbert Spohn, Walter Thirring, Cédric Villani, Anton Zeilinger

Complex Analysis, Operator Theory and Applications to Mathematical Physics

Organizers: F. Haslinger (University of Vienna), E. Straube (Texas A& M University), H. Upmeier (University of Marburg)

Dates: October 1 - October 15, 2006 and November 6 - November 17, 2006

Budget: ESI €8.112,85,–

Preprints contributed: [1763], [1765], [1793], [1800], [1802], [1803], [1804], [1830], [1836], [1866], 1882]

Report on the programme

During the period October 1-15, 2006, as part of the follow-up Programme on Complex Analysis and Applications, there was a special activity concerning relations between Complex and Harmonic Analysis on Symmetric Domains. Participants included H. Upmeier (Marburg, Organizer), J. Arazy (Haifa), M. Englis (Prague) and Y. Neretin (Moscow/Vienna). A mini-workshop on this topic took place on October 5, 2006, with 4 talks given by these participants.

Work in progress includes new concepts concerning complex and harmonic analysis on symmetric spaces, Jordan algebras and quantization theory, with special emphasis on, e.g., Recursion formulas for Weyl quantization on symmetric domains, Intertwiners for vector-valued Bergman spaces and Jordan-Grassmann manifolds, Moyal star-products on real symmetric domains and asymptotic expansions, or Non-convex Hardy spaces and Toeplitz operator algebras.

In November 2006 the analysis part of the programme was continued with 14 participants. The schedule of talks together with short abstracts is available from

http://www.mat.univie.ac.at/∼has/pro06.html

It was important that two French colleagues, P. Charpentier (Université Bordeaux) and D. Popovici (Université Toulouse), who could not come for the main programme in 2005, were able to participate in the follow-up programme. Their contributions on estimates of the Szegö projection and singular Morse inequalities were of outstanding interest. Most of the other participants reported about new results and ideas coming from discussions of the main programme one year ago.

In this connection it was very helpful that B. Helffer gave his ESI-Senior Lectures "Introduction to the spectral theory for Schrödinger operators with magnetic fields and applications" in 2005/2006. His lectures were attended by many participants of the main programme and led to several new and far-reaching results by applying spectral methods for Schrödinger operators to problems in Complex Analysis. It turned out that parts of the important Hörmander L^2-estimates for the solution of the inhomogeneous Cauchy-Riemann equations can be derived from spectral properties of Schrödinger operators with magnetic fields (see ESI preprint 1800).

Finally Klas Diederich resumed the state of the art in Complex Analysis by a series of survey talks.

Invited Scientists: Jonathan Arazy, Miroslav Englis, Yurii Neretin, Harald Upmeier, Philippe Charpantier, Klas Diederich, Roman Dwilewicz, Dariush Ehsani, Friedrich Haslinger, Bernard Helffer, Martin Kolar, Slawomir Kolodziej, Dan Popovici, Andy Raich, Sonmez Sahutoglu, Aleksander Strasburger

Seminar Sophus Lie

Organizers: D. Burde (University of Vienna), P.W. Michor (University of Vienna), W.A.F. Ruppert (University of Natural Resources and Applied Life Sciences, Vienna)

Dates: November 3 - November 4, 2006

Budget: No ESI support

Report on the programme

Seminar Sophus Lie is a joint seminar of a group of mathematicians interested in the theory of Lie groups, Lie algebras and related topics. It was founded in 1990/91. The seminar meets at one of the participating research groups/universities two times per year. The meeting at ESI centered around questions in Lie theory proper and relations with geometry and (harmonic) analysis.

Programme:

Karl-Hermann Neeb: Pro-Lie groups which are infinite-dimensional Lie groups
Helge Glöckner: Classification of the simple totally disconnected contraction groups
Christoph Wockel: Approximation Theorems for Locally Convex Manifolds, Lie Groups and Principal Bundles
Mark Losik: Lifts of diffeomorphisms of orbit spaces for representations of compact Lie group
Claudio Gorodski: Polar actions on compact rank one symmetric spaces are taut Dietrich Burde: Affine Actions on nilpotent Lie Groups
Wolfgang Moens: T-groups: Cohomology and polynomial crystallographic actions Istvan Heckenberger: A generalization of Coxeter groups, root systems, and Masumoto's theorem
Yurii Neretin: On natural kernels on symmetric spaces
Wolfgang Bertram: The projective geometry of a Lie algebra and its intrinsic subspaces
Detlev Poguntke: The dual of L1K(N)for Heisenberg groups N and compact commutative K
Brigitte Breckner: A multiplicity result for systems of hemivariational inequalities and its applications
Aleksander Strasburger: Generalizations of the Pizzetti's formula for the Heisenberg group and spherical harmonics
Cornelia Vizman: Momentum maps for Lie algebra 2-cocycles
Alice Fialowski: On filiform Lie algebras and their deformations

Invited Scientists: Alexander Alldridge, Wolfgang Bertram, Brigitte Breckner, Dietrich Burde, Andreas Čap, Alice Fialowski, Helge Glöckner, Claudio Gorodski, Istvan Heckenberger, Joachim Hilgert, Troels Johansen, Martin Laubinger, Mark Losik, Peter W. Michor, Wolfgang Moens, Karl-Hermann Neeb, Yurii Neretin, Detlev Poguntke, W.A.F. Ruppert, Günter Schlichting, Aleksander Strasburger, Cornelia Vizman, Christoph Wockel

Modern Methods of Time-Frequency Analysis

Organizers: H.G. Feichtinger (University of Vienna), K. Gröchenig (University of Vienna)

Dates: November 20 - November 24, 2006

Budget: ESI €5.187,–

Report on the programme

This two weeks workshop was a follow-up activity to the programme with the same title in spring 2005. Ten participants of the main programme attended this meeting to discuss progress that has been made since 2005.

Two of the participants (Jeff Hogan, who is on a sabbatical at this time, and J.P. Antoine, who has recently retired from his position) could stay longer and had intensive interactions with the members of the NuHAG group.

Particularly close cooperation occurred between Remi Gribonval and Holger Rauhut, Yura Lyubarskij and Karlheinz Gröchenig, Gerd Teschke and Stephan Dahlke, and J.P. Antoine and Hans G. Feichtinger.

The talks given during these 2 weeks are related to important topics in time-frequency analysis. "Partial inner product space" (J.P. Antoine) describes families of Banach spaces, a situation

similar to the consideration of families of modulation spaces in TF-analysis. "Compressed sensing" is a booming recent branch of signal analysis. It is concerned with the reconstruction of sparsely composed signals (with unknown "carrier") from a relatively small number of measurements. Talks by R. Gribonval, B. Toressani and H. Rauhut discussed recent developments.

Localization operators (N. Teofanov) are a central topic of TF-analysis, here it is extended to the setting of ultra-distributions. Jeff Hogan presented connections between the classical distribution spaces (BMO, Hardy) and frame operators. P. Vanderghynst was presenting interesting new results on multi-modal signals as they arise in audio-visual data processing. The connection between uncertainty principles and vector quantization were the topic of Y. Lyubarkii's talk. While G. Teschke's presentation was concerned with iterative algorithms suitable for the solution of ill-posed problems, the talk by S. Dahlke described the advantage of frame decomposition for the approximation of linear problems, the advantages compared to Riesz basis representations, for linear as well as non-linear problems.
Overall the workshop was very fruitful and the organizers and participants would like to thank the ESI team for the excellent organization and support

Invited Scientists: Jean-Pierre Antoine, Stefan Dahlke, Hans Georg Feichtinger, Remi Gribonval, Karlheinz Gröchenig, Jeffrey Hogan, Yurii Lyubarskii, Peter Soendergaard, Gerd Teschke, Nenad Teofanov, Bruno Torresani, Pierre Vandergheynst

Quantum Statistics

Organizers: K. Audenaert (Imperial College London), F. Verstraete (University of Vienna), M. Wolf (Max-Planck-Institut für Quantenoptik, Garching)

Dates: November 27 - December 1, 2006

Budget: ESI €3.375,–

Report on the programme

The workshop brought together people from the diverse communities of mathematical physics and quantum information theory, and there was a very interesting interchange of ideas. A few new results emerged through the workshop, and those are currently in the process of being written down:

1) Asymptotic error exponents in asymmetric hypothesis testing: A collaboration was started between Arleta Szkola, K. Audenaert and F. Verstraete, in which we solved a long-standing open problem in the field of hypothesis testing. In particular, the Hoeffding-Blahut-Csiszar-Longo bound was proved in the quantum setting, which corresponds to the most general setting in quantum hypothesis testing and involved the solution of a few highly nontrivial matrix inequalities. This result is currently being written up and will be submitted to Communications in Mathematical Physics.

2) A different line of discussion was concerned with the use of non-commutative central limit theorems in quantum statistics and quantum information. Two presentations on that topic by A. Jencova and M. Wolf showed that several asymptotic problems in statistical inference, entanglement theory and quantum channel capacities can be considerably simplified by exploiting central limit ideas. This allows in many cases to resort to quasi-free systems - bosonic as well as fermionic. In addition to these quite expected cases an independent central limit argument could be constructed for spin systems in which stabilizer states emerge as natural generalizations of Gaussian states in finite dimensional Hilbert spaces.

In general, it seems that the conference was a success both for the participants and the organizers, and this was to a large extent due to the very stimulating environment of the ESI and the perfect and very professional assistance of the local ESI-staff.

Invited Scientists: Konrad Audenaert, Vladimir Buzek, Ignacio Cirac, Anna Jencova, Barbara Kraus, Adam Nagy, Denes Petz, Rüdiger Schack, Norbert Schuch, Arleta Szkola, Frank Verstraete, Michael Wolf, Jakob Yngvason

"Challenges in Particle Phenomenology", 3rd Vienna Central European Seminar on Particle Physics and Quantum Field Theory

Organizer: H. Hüffel (University of Vienna)

Dates: December 1 - December 3, 2006

Budget: ESI €2.250,–. Also supported by the Austrian Federal Ministry for Education, Science and Culture, by the Institute for High Energy Physics of the Austrian Academy of Sciences and by the Vienna Convention Bureau.

Report on the programme

Advisory Board: A. Bartl (Vienna), G. Ecker (Vienna), W. Majerotto (Vienna), F. Pauss (Zurich and CERN), P. Zerwas (DESY).

The subject was centred on particle phenomenology. The Large Hadron Collider LHC and a future linear collider will be the main tools to probe physics at the Tera scale. In particular, one will be able to test current ideas about elektroweak symmetry breaking and the origin of mass. In the seminar recent developments were covered, of the Standard Model, Higgs physics, supersymmetry, extra dimensions, and the connection to cosmology.

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 Scientists: B. Allanach, C. Anastasiou, D. Aristizabal, N. Arkani-Hamed, A. Ayaz, A. Bartl, E. Bartos, P. Benes, J. Chyla, G. Colangelo, A. Daleo, F. Deppisch, G. Dissertori, P. Dita, G. Ecker, M. Endo, S. Fajfer, J. Fischer, A. Glück, W. Hollik, H. Hüffel, J. Kamenik, T. Kernreiter, W. Kilian, M. Kladiva, H. Klapdor-Kleingrothaus, N. Kosnik, S. Kraml, G. Leontaris, Z. Li, W. Majerotto, T. Mannel, M. Martinis, H.Martyn, I. Melo, G. Palma, F. Palorini, F. Pauss, W. Porod, A. Provenza, T. Robens, K. Rolbiecki, A. Smetana, F. Takahashi, B. Trpisova, N. Uekusa, T. Varin, J. Virto, J. Winter, M. Yamaguchi, M. Zdrahal, P. Zerwas

Causes of Ecological and Genetic Diversity

Organizers: R. Bürger (University of Vienna), U. Dieckmann (International Institute for Applied Systems Analysis)

Dates: December 11 - December 16, 2006

Budget: ESI €3.979,92, Wiener Wissenschafts-, Forschungs- und Technologiefonds €7.218,26, International Institute for Applied Systems Analysis €1.000,–

Report on the programme

The talks and discussions in this workshop revolved around one of the key topics of theoretical and empirical research in evolutionary biology: understanding the origin and maintenance of genetic and ecological diversity. Such diversity includes the ubiquitous variation among individuals within a single population, the widespread differences of spatially distributed populations of the same species, as well as the stunning diversity among species. The mechanisms generating and maintaining this variation are not fully understood, and even less so are the processes involved in the formation of new species. The workshop brought together theoretical geneticists, theoretical ecologists, and biomathematicians working in these fields, as well as empirical and experimental biologists.

A major scientific challenge in understanding biological diversity concerns the development and analysis of mathematical models that incorporate enough genetics and ecology to be realistic, and yet remain tractable. The last decade has brought about substantial advances, both theoretical and empirical, in explaining the maintenance of genetic variation, as well as of the origin and maintenance of ecological variation. Changing ecological conditions, newly available habitats, and evolution under frequency-dependent interactions can all lead to the emergence of new ecological niches. Under such conditions, subsequent evolutionary adaptations can result in intraspecific diversity, radiation, and speciation. Recently, new mathematical approaches have been developed in ecology and population genetics that offer the possibility for a unified treatment providing new and deeper insights. One is adaptive dynamics theory, a mathematical extension of evolutionary game theory tailored to studying long-term evolutionary dynamics driven by frequency-dependent ecological interactions. The other is multilocus genetics applied to ecologically relevant quantitative traits. Approaches of this synthetic type have great potential: they can be generalized and extended to address problems of long-term evolution by studying the fate of new mutations and they are applicable to central evolutionary problems such as the colonization of empty niches, the maintenance of variation in heterogeneous environments, or adaptive speciation. The talks at this workshop reported recent advances in these fields, provided reviews of empirical and experimental evidence, and, most importantly, concentrated to a large extent on the interaction of these fields by presenting new and fresh approaches right at their interface. Extensive, also plenary, discussions complemented the talks and suggested new routes for future research.

Invited Scientists: Dan Bolnick, Reinhard Bürger, Ulf Dieckmann, Varvara Fazalova, Andreas Futschik, Florian Gach, Joachim Hermisson, Josef Hofbauer, Hiroshi Itoh, Vincent Jansen, Mark Kirkpatrick, Eva Kisdi, Michael Kopp, Olof Leimar, Sabin Lessard, Geza Meszena, Hans Metz, Rubert Mazzucco, Minh Ha Quang, Howard Rundle, Akira Sasaki, Christian Schlötterer, Kirstan Schneider, Michael Turelli, Sander van Doorn

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.

An additional component in this programme was the *Educational Workshop on Discrete Probability*, organized by Vadim Kaimanovich (Rennes), Klaus Schmidt (University of Vienna and ESI) and Wolfgang Woess (University of Technology, Graz). The workshop took place at the Erwin Schrödinger Institute from March 12 until March 25, 2006 and was financed by the European Science Foundation together with the ESI. 24 young researchers were supported by the Junior Research Fellows Programme.

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

1st deadline: 31.03.2006
Number of applications: 27
Number of accepted applicants: 12
Number of months granted: 22 for 2006, 9 for 2007

2nd deadline: 31.10.2006
Number of applications: 42
Number of accepted applicants: 15
Number of months granted: 41 for 2007

Junior Research Fellowships in 2006 (excluding the participants of the Workshop on Discrete Probability)

Name	Gender	Duration	Nationality
Katie Bloor	female	27/03 - 31/08	Great Britain
Francesco D'Andrea	male	02/05 - 31/05	Italy
Francesco D'Andrea	male	04/07 - 31/07	Italy
Spyridon Dendrinos	male	27/09 - 30/11	Greece
Martyn De Vries	male	06/04 - 30/06	Netherlands
Karla Diaz-Ordaz	female	21/03 - 20/09	Mexico
Pierluigi Falco	male	07/06 - 04/08	Italy
Anton Galaev	male	01/01 - 31/01	Russia
Victor Junwei Guo	male	01/05 - 31/07	China
Eman Hamza	female	01/06 - 31/07	Egypt
Nataliya Ivanova	female	02/11 - 28/12	Ukraine
Adam Joyce	male	01/01 - 30/06	Great Britain
Wolfgang Lechner	male	01/01 - 30/06	Austria
Richard Miles	male	14/03 - 14/07	Great Britain
Thierry Monteil	male	06/02 - 21/04	France
Ian Morris	male	07/03 - 10/06	Great Britain
Milan Mosonyi	male	28/08 - 27/11	Hungary
Tomasz Paterek	male	08/06 - 07/08	Poland
Tomasz Paterek	male	01/09 - 31/12	Poland
Evangelia Petrou	female	27/04 - 27/07	Greece
Michail Pevzner	male	01/01 - 31/01	Russia
Peter Pickl	male	06/06 - 06/08	Germany
Pietro Polesello	male	08/05 - 08/08	Italy
Catherine Richard	female	03/04 - 30/06	France
Hisham Sati	male	01/05 - 30/06	Lebanon
Jean Savinien	male	01/05 - 30/06	France
Emanuel Scheidegger	male	01/04 - 31/07	Switzerland
Evelina Shamarova	female	01/10 - 31/12	Russia
Mathieu Stienon	male	11/05 - 11/07	Belgium
Alexandr Usnich	male	01/06 - 31/07	Belarus

Preprints contributed: [1801], [1808], [1817], [1822], [1823], [1825], [1841], [1842], [1843], [1844], [1877], [1885], [1895], [1896]

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. The coordinator of this programme was Joachim Schwermer.

This year's programme concentrated on the following lecture courses:
Bernard Helffer (Université Paris Sud, Orsay), Winter 2005/2006, on: Introduction to the Spectral Theory for Schrödinger Operators with Magnetic Fields and Applications
David Masser (Universität Basel), Summer 2006, on: Heights in Diophantine Geometry.
Mathai Varghese (University of Adelaide), Summer 2006, on: K-theory Applied to Physics.
Ioan Badulescu (Université de Poitiers), Winter 2006, on: Representation Theory of the General Linear Group over a Division Algebra.
Thomas Mohaupt (University of Liverpool), Winter 2006, on: Black Holes, Supersymmetry and Strings.

Alan Carey (Australian National University, Canberra) actively participated as Clay Mathematics Institute Research Scholar in the programme on "Gerbes, Groupoids and Quantum Field Theory" from May 7 - August 9, 2006.

Bernard Helffer: Introduction to the Spectral Theory for Schrödinger Operators with Magnetic Fields and Applications

Course: After recalling some elements of perturbation theory concerning the links between approximate eigenvectors or eigenvalues and exact eigenvectors or eigenvalues, we have presented the main properties of the Schrödinger operators with magnetic fields. We then gave some elements in semi-classical analysis : harmonic approximation, WKB constructions and analysis of the decay of eigenfunctions. We then analyze specific models occurring in the theory of Super conductivity theory. We conclude by the application to the analysis of the bottom of the spectrum of the Neumann realization of the Schrödinger operator with magnetic fields in connection with the superconductivity.

The audience was between 6 and 15, depending on the period. This included Professors of the Department of Mathematics in the University of Vienna, Members or Visitors of the Institute, Post-Docs and a few students. The first part was presented during a period where a programme in Complex Analysis was running. We have used this opportunity for presenting the links between the Theory of Schrödinger Operators with magnetic fields and d-bar problems in weighted space.

In the second part, I emphasized the applications to superconductivity. This problem is quite close to the Bose-Einstein condensation theory (which is one of the research areas in the group of J. Yngvason).

Written notes of the course are available on my Web Page:
http://www.math.u-psud.fr/∼helffer/

Research: I was mainly working with Professor T. Hoffmann-Ostenhof in the field Spectral Theory and nodal Domains. We have made quite significant progress in understanding the links between optimal partitions and nodal domains. Because this subject is at the intersection of many fields, we invited a specialist in variational calculus, S. Terracini of the University of Milano. This visit was very fruitful and has led to one article in preparation.

Although unexpected before I arrived at the Institute, common interests appeared with F. Haslinger, one of the organizers of the programme in Complex analysis. The fruitful discussions will lead to a joint paper in the near future.

Finally, other visitors were F. Nier (ESF financed, invitation together with J. Yngvason), A. Laptev (invited by T. Hoffmann-Ostenhof), and the PhD Students A. Kachmar (ESF financed) and E. Rosenberger (ESI financed).

Preprint contributed: [1800]

David Masser: Heights in Diophantine Geometry

Course plan: Heights arose naturally in connexion with Weil's proof in 1928 of the finite generation of the group of rational points on an abelian variety, and shortly afterwards in 1929 Siegel used heights in his proof of the finiteness of the set of integral points on a curve of positive genus. Somewhat later they were recognized as a very efficient tool for measuring algebraic numbers in the context of standard constructions in transcendence theory. Nowadays it is impossible to do much diophantine geometry without them.

Our course will start without diophantine geometry or even algebraic number theory. We will give basic definitions and properties, and then prove, at least for the harmless curve $x + y = 1$, a special case of a famous 1992 result of Zhang about lower bounds. Using elementary algebraic number theory we will then establish some additional properties of heights and give a shorter second proof of Zhang's result.

In 1997 Bilu with his Equidistribution Theorem provided a considerable strengthening of Zhang's result. We will give a proof based on an analytic inequality of Erdös-Turán together with a standard transcendence construction. This opens the way for a treatment of the more classical 1979 result of Dobrowolski, also about lower bounds, which remains one of the most useful for applications.

More recently there has been interest in upper bounds for heights. We will give a simple proof that the height is bounded above for points on the curve $x + y = 1$ whose coordinates x, y are multiplicatively dependent; this means that the points lie in the union of all proper subgroups of the algebraic group $\mathbf{G}_m^2$.

We will also give an introduction to the theory in higher dimensions. Zhang proved his lower bound result for arbitrary subvarieties $\mathcal{X}$ in any $\mathbf{G}_m^n$; now it is necessary to exclude points lying on subgroups contained in $\mathcal{X}$. By contrast, the upper bound result is known essentially only for curves in $\mathbf{G}_m^n$. There has been some recent work on planes, but still hardly anything is known for arbitrary surfaces. The general case is covered only by conjectures.

The upper bounds can be applied to give new finiteness statements. Thus if $\mathcal{C}$ is a typical curve in $\mathbf{G}_m^n$, then there are only finitely many points on $\mathcal{C}$ for which there are two independent multiplicative relations on the coordinates. The proof uses a deep generalization of Dobrowolski's Theorem established in 1999 by Amoroso and David. If time permits, we will treat in detail the case $n = 3$, where it suffices to use another generalization due to Amoroso and Zannier in 2000.

Just as for upper bounds, the corresponding finiteness statements for arbitrary varieties are covered only by conjectures. Interestingly enough these have recently turned up in other contexts: Zhang himself (unpublished), Zilber 2002 in connexion with Schanuel's Conjecture in transcendence theory, and Pink 2005 who treats the most general case of mixed Shimura varieties.

This turned out indeed to be an accurate description of what I said. To my surprise I did manage to give a fairly detailed proof of Zhang's result in higher dimensions, and also of the finiteness result in three dimensions assuming Amoroso-Zannier. I had intended to prove this latter result, but there was no time. There was not quite enough time to discuss very fully the related conjectures of Zhang, Zilber, and Pink.

I very much enjoyed giving this course. Several of the proofs turned out to be quicker and more direct than anything in the published literature, and some of this will be written up in a survey-type note intended for publication. I was gratified to find that my title "Heights

in Diophantine Geometry" was exactly the title of a book by Bombieri and Gubler that was published about half-way through the course, and also that my contents were somewhat similar to parts of theirs. But my course had rather fewer prerequisites.

My research activities were not at all disjoint from my teaching activities. Thus the connexions with the conjectures of Zhang, Zilber, and Pink were worked out in detail in section 5 of a paper *Anomalous subvarieties - structure theorems and applications* (31 pages), written with Bombieri and Zannier, whose writing up I was able essentially to complete in ESI and the month afterwards in Pisa. It will be submitted for publication in the next few days. I was also able to do the same to an older paper *Intersecting a plane with algebraic subgroups of multiplicative groups* (33 pages), also with Bombieri and Zannier. These had been the major goals of my sabbatical.

But for me the stay at ESI was particularly valuable in that I was able to begin my collaboration with Harm Derksen. This project had been in the air for some time, but it was my sabbatical, as well as Derksen's visit to ESI, that gave the starting impetus. Derksen's talk dealt with his work in positive characteristic, and in this work he had come across sets which looked familiar to me from my paper *Mixing and linear equations over groups in positive characteristic*, Israel J. Math. 142 (2004), 189-204. I had written this paper after a very profitable visit to ESI in March 2002 and many discussions there with Klaus Schmidt. Since then I had always wanted to return to the subject, both from the point of view of the pure theory and also the applications to mixing problems in dynamical systems of algebraic origin.

During my 2006 stay at ESI we did several things. First, we convinced ourselves that the methods of my paper are completely effective in the technical sense. This was not quite straightforward, as the things that are to be estimated can easily be infinite and so one must use some sort of structure to see what exactly should be estimated. The structure established in my paper was somewhat rudimentary, and in ESI we worked out a much more precise structure in the case of equations with four terms (the case of three terms was too simple to be convincing). We then began to consider the general case (at the moment without estimates), but it was not until my Pisa visit a month later that we finally succeeded with this; the final statement bears a resemblance to the famous conjecture of Bombieri, in zero characteristic, about rational points on varieties of general type. We already knew that this result would probably solve another open problem in mixing: namely to find effectively the mixing order of a given action. And then while I was in Pisa, Klaus Schmidt proposed to go even further and find in some sense all the non-mixing sets of this order. This problem is a bit closer to that originally considered by Derksen (whose original methods, involving automata, appear at first sight to be completely different). Work on the project, now quite large, is still proceeding: the general case has to supplemented by explicit estimates (a completely natural way of doing this is still not quite clear in general), and all the applications to mixing have to be worked out in detail.

Thus my stay at ESI was just as profitable as last time in 2002, and for more or less the same reasons: the highly unbureaucratic organization, the excellent working conditions, and the sheer enjoyment of being in Vienna (even when the public transport was disrupted by presidential motorcades).

Mathai Varghese: K-theory Applied to Physics

I would like to thank the ESI for the appointment as an SRF (1^{st} March-30^{th} June 2006), which gave me an opportunity to continue doing productive research as well to enjoy the city of Vienna, its culture and surrounds. The first month my stay at ESI overlapped with the "RDSES/ESI Educational Workshop on Discrete Probability", while the final two months overlapped with the "Gerbes, Groupoids, and Quantum Field Theory" and the "Homological Mirror Symmetry" programmes at ESI, all of which I actively participated in.

Course: During my stay at ESI, I gave a course of advanced graduate lectures entitled "K-theory applied to Physics" and I plan to edit the lecture notes of my course into a book in the ESI

publication series. The first half of my course was on some mathematical models of the integer and fractional Quantum Hall effect, for which the experimentalists who discovered these effects were awarded the Nobel Prizes in 1985 and 1998 respectively. The classical geometry of electrons in solids and the passage to noncommutative geometry produced by the presence of a magnetic field, enables one to model the quantum Hall effect. The quantum Hall effect is 2 dimensional: the Euclidean case simulates the single electron model of the integer quantum Hall effect as studied by Bellissard and coauthors, whereas the hyperbolic case simulating the multi-electron interactions and models the fractional quantum Hall effect, and was initiated by my research with my coauthors. The Hamiltonian is the magnetic Schrödinger with periodic electric potential and magnetic field, and is invariant under magnetic translations. The noncommutativity of the magnetic translations forces the algebra of observables to be a noncommutative geometry. The Kubo conductance is argued to be a cyclic 2-cocycle associated to the Bergman metric, on the noncommutative geometry of observables. The range of values of the Kubo conductance on measurable quantities (i.e. projections in the noncommutative geometry of observables) are derived to be integer multiples of orbifold Euler characteristics, which form a definite set of fractions. This result compares the Kubo 2-cocycle with the 2-cocycle associated to the hyperbolic metric, and uses the twisted Baum-Connes conjecture as well as higher C* algebra index theorems.

The second half of my course was on the rudiments of the mathematics of String Theory, which is arguably the most exciting research area in modern mathematical physics. String Theory is known to the general public as the "Theory Of Everything", being the most successful attempt to date at unifying Relativity Theory (or theory of large scales) and Quantum Theory (or theory of microscopic scales). The impact of String Theory is not just felt in physics, but it also has profound interactions with a broad spectrum of modern mathematics, including noncommutative geometry, K-theory and index theory. I gave arguments to show that in the presence of a background H-flux, (an extended version of the magnetic field) spacetime becomes a (mildly) noncommutative geometry, which is locally Morita (hence physically) equivalent to smooth functions on usual spacetime. Such noncommutative geometries are classified by their Dixmier-Douady invariant and are geometrically constructed via bundle gerbes. The D-brane charges and Ramond-Ramond fields in type II String Theory are classified by the K-theory of this noncommutative geometry, called twisted K-theory. I gave some geometric realizations of twisted K-theory. An important fundamental symmetry of type II String Theory is called T-duality. It relates String Theory compactified on small radius spacetimes to String Theory compactified on large radius spacetimes, which surprisingly could differ both in geometry and topology to the original spacetime. I proposed an axiomatic definition of T-duality for general noncommutative geometries. The examples of noncommutative geometries arising from the presence of a background flux, on spacetimes that are compactifed as principal torus bundles were briefly analyzed, and shown to satisfy these axioms, using Green's Imprimitivity Theorem, Connes Thom Isomorphism Theorem and Takai Duality.

Research activities: During my stay at ESI, I have had a number of visitors, who have either collaborated with me or have discussed mathematics with me, on research that is ongoing. The visitors include, Dr. Sakura Shafer-Nameki (U. Hamburg), Prof. Siye Wu (U. Colorado), Mr. David Roberts (U. Adelaide), Prof. Peter Bouwknegt (ANU), Dr. Keith Hannabuss (U. Oxford), Dr. Hisham Sati (Yale U.), Dr. Jacek Brodzki (U. Southampton), Prof. Jonathan Rosenberg (U. Maryland) and Dr. Urs Schreiber (U. Hamburg). I have just completed a preprint (with Brodzki, Rosenberg and Szabo) that will be placed on the ESI preprint archive shortly. During my stay at ESI, I have given a Plenary talk at the workshop entitled "Twisted K-theory and Gerbes", Clermont-Ferrand on March 24-25; an invited speaker at the BIRS conference on "Noncommutative Geometry" at Banff (Canada), April 8-13; an invited talk at the MFO, Oberwolfach conference entitled "Zeta Functions, Index and Twisted K-Theory; Interactions with Physics", Germany, April 30 - May 6; an invited talk at the Erwin Schrödinger Institute (Vienna) conference entitled "Gerbes, Groupoids, and Quantum Field Theory", May 9-13; a

Plenary talk at the Mathematical Institute (University of Oxford) "K-theory Day" in honour of the Fields medalist, Prof Daniel G. Quillen, at the occasion of his retirement, May 22, 2006; ZMP colloquium talk (DESY, U. Hamburg), June 1; a Plenary talk at the Journal of Geometry and Physics congress, SISSA International School for Advanced Studies, Trieste, Italy, June 24-28.

Preprint contributed: [1813]

Ioan Badulescu: Representation Theory of the General Linear Group over a Division Algebra

Course: The course was divided into three parts. In the first part I recalled without proofs general facts about representations of reductive groups defined over a p-adic field (called in the sequel p-adic groups): construction of the Hecke algebra H of a p-adic group G; irreducible admissible representations of G correspond to irreducible modules over H; one may so define the distribution character of a representation; following Harish-Chandra, the distribution character is locally integrable; definition of parabolic induction and parabolic restriction (i.e. Jacquet functor), and definition and properties of cuspidal, square integrable and tempered representations.

In the second part I focused on the general linear groups $GL_n(F)$ and $GL_n(D)$, where F is a local field of zero characteristic and D is a central division algebra of finite dimension over F. I recalled without proofs the Zelevinsky classification of smooth irreducible representations of $GL_n(F)$ and the Tadić classification of *unitary* smooth irreducible representations of $GL_n(F)$. I stated the Jacquet-Langlands correspondence and gave the consequences of this correspondence for $GL_n(D)$, Tadić's classification of smooth irreducible representations of $GL_n(D)$ and Tadić's conjectures on the unitary dual of $GL_n(D)$, together with a review of the last developments in this area.

In the last six lectures, I gave the complete proof of the Jacquet-Langlands correspondence stated before, following Jacquet-Langlands and Deligne-Kazhdan-Vigneras. Before, I recalled what was needed about representations of reductive groups over global fields, the simple Kazhdan-Deligne trace formula, finite multiplicity and multiplicity one theorems in the automorphic spectrum, and also some local tools like orbital integrals and the orthogonality of characters.

Research: I spent most of my time preparing the content and text of my lectures. It was a good opportunity to search for suitable references and to give proofs for those results that everybody knows are true and nobody knows where they are proven. I also composed sets of problems related to the course. In a parallel seminar, graduate students at the university of Vienna that attended the course and I discussed some additional material as well as solutions to these problems. Currently, I'm writing a book based on the lecture notes.

Motivated by a question of Professor Schwermer, I started a collaboration with Professor Tadić from the University of Zagreb whom I could invite to Vienna thanks to the grant provided by the Senior Research Fellowship programme for this purpose. We are working together on the problem of Jacquet-Langlands local transfer of unitary representations in the real case ($GL_{2n}(\mathbb{R})$ to $GL_n(\mathbb{H})$), and the global transfer between GL_n and the group of invertible elements of a division algebra which may be not split at infinite places.

Other visitors with whom I discussed possible applications of my approach to the Jacquet-Langlands correspondence were N. Grbac and G. Muic, the latter one invited by ESI.

The Institute and the city: This was my first visit to Vienna, and I have been very impressed by the beauty and the atmosphere of the city. I found a great ambience at the Institute

which is a very nice place to work. I want to thank Professor Schwermer for the invitation and the staff for the warm reception.

Thomas Mohaupt: Black Holes, Supersymmetry and Strings

Course: Starting from the Schwarzschild and Reissner-Nordström solutions of Einstein-Maxwell theory, we discussed properties of event horizons, and in particular of Killing horizons. The proofs of the zeroth and first law of black hole mechanics were outlined, using Robert Wald's framework, which applies to any diffeomorphism invariant action, including those with higher curvature terms. The distinguished properties of the extremal Reissner-Nordström solution (and its generalization, the Majumdar-Papapetrou solutions) motivated us to consider black holes solutions of supergravity theories. After introducing the concepts of central charges, BPS states, BPS solitons and Killing spinors, we showed that the extremal Reissner-Nordström solution is a supersymmetric solution of pure $N = 2$ supergravity. To set the stage for matter-coupled supergravity, we introduced the superconformal calculus and special Kähler geometry, and then outlined the construction of $N = 2$ supergravity coupled to an arbitrary number of vector supermultiplets. Then we reviewed the existing results on the classification of supersymmetric solutions in these theories and discussed how higher curvature terms modify supersymmetric black hole solutions and their entropy. Finally we gave an example where the statistical black hole entropy derived from string theory disagreed, beyond leading order, with the naive Bekenstein-Hawking area law, but completely agreed with Wald's modified definition of black hole entropy, which deviates from the area law if higher curvature terms are present.

We delivered a total of 9 two-hour lectures and seminars. During the seminars students were encouraged to present their solutions to problems set during the lectures, and details of calculations not covered in the lecture for lack of time were explained.

Research: During the indicated period I revised and substantially extended an overview article on special geometry, which will appear in the Handbook of Pseudo-Riemannian Geometry and Supersymmetry. I constructed instanton solutions in the vector multiplet sector of $N = 2$ supergravity. Together with Gabriel Cardoso from LMU München, who was visting me (financed by ESI), I investigated how to apply Rademacher-type expansions to check the relations between black hole partition functions and topological string partition functions, which have been proposed H. Ooguri, A. Storminger and C. Vafa.

Alan Carey (Clay Mathematics Institute Research Scholar)

The primary purpose of my period as Clay Research Scholar was to participate actively in the three month ESI programme on Gerbes, Groupoids and Quantum Field Theory.

The programme itself was quite crowded with workshops and there were also conferences and workshops associated with other parallel programmes on mathematical physics some of which impinged on the core programme.

I spent the period May 7-August 9 at ESI with brief visits to SISSA the Australian National University and to the University of Copenhagen (all of about four days each, some including a weekend). The visits were primarily for the purposes of furthering the research I was undertaking at ESI.

My main role in the ESI programme was informal. I chaired sessions in two of the workshops. The very full nature of the ESI programme mitigated against my organising more large scale activities.

The greatest call on my time while at ESI was conducting research on various problems and I will explain these below. I also took the opportunity to speak with the young researchers who

were progressing the field on which the programme was focussed. From my research grant in Australia I funded a postdoctoral fellow (Bai-Ling Wang) from the Australian National University to attend two ESI workshops. Wang talked during the first workshop (May 7-11) about his recent research. He also engaged in informal discussion with other young researchers and contributed many ideas to their research problems.

Wang also began a collaboration with Jouko Mickelsson and myself and as a result we have a joint work in progress.

I started two other research projects while at ESI on the theme of the programme however a major proportion of my time was spent on research projects that were on-going from the period prior to my visit to ESI. I list all of this below. I gave some informal talks on this current work.

Probably the highlight of my time was solving a problem that I had been thinking about for over a year. In collaboration with John Phillips and Adam Rennie I had been working on a novel kind of index theory and trying to complete a paper on an example. We had been struggling with the question of what the topological meaning of our index could be (we had an analytic formula). As the index is associated to a family of Fredholm operators it was natural to seek a meaning using some if the ideas that were the focus of the workshop (gerbes, twisted K-theory etc). However these attempts all foundered and the answer lay in a different direction. We found that the index we were seeking to explain had been seen in statistical mechanics and quantum field theory as the relative entropy of a pair of KMS states. Subsequently we realised it also has the flavour of an equivariant index but at the moment we cannot make this precise. Nevertheless we now have a new and interesting line of enquiry, namely, exploit the physics ideas (which have to do with the Jones index of subfactors) in our setting.

List of Projects.

(i) Index theory and gerbes.

Gerbes arise in the Atiyah-Singer family index theorem in the odd dimensional case. The so-called Dixmier-Douady class of the gerbe is the degree three component of the K-theory class associated with a family of Fredholm operators. In work with Jerry Kaminker and Ron Douglas I began to investigate the question of whether there are geometric structures associated with the higher degree classes in the case when the gerbe class vanishes. We have only a few modest results at this stage.

(ii) Chern-Simons gauge theories.

These were a recurring theme in the workshop. I started a discussion with Christoph Schweigert and Michael Murray about Chern-Simons gauge theories on manifolds with boundary. We wrote some brief notes which may develop into a joint project.

(iii) Twisted K-theory

There are difficulties in understanding what exactly is the right notion of Chern character in twisted K-theory. The successful points of view so far really describe a Chern character map which depends on Deligne data not on the twisted K-theory data. Following ideas of Freed I have some notes towards a paper with Michelsson and Wang entitled 'Differential twisted K-theory and twisted eta forms'.

(iv) Ongoing projects.

(a) proof read and submitted final version of a survey paper entitled 'Semifinite Spectral Triples Associated with Graph C^*-Algebras'

(b) worked towards completing the following linked series of papers:
APS Boundary Conditions, KK-Theory and Spectral Flow in Graph C*-Algebras

The Chern Character of Semifinite Spectral Triples: Math OA/0611227
Twisted Cyclic Theory and the Modular Index Theory of Cuntz Algebras
The Modular Index Theory of $SUq(2)$
The Dixmier trace and asymptotics of zeta functions: Math OA/0611629

Preprint contributed: [1872]

Seminars and colloquia outside of conferences

2006 01 09, J. Cogdell: “On Artin L-functions”
2006 01 09, P. Ullrich: “A Glance at Emil Artin’s Laboratory - Letters to His Academic Teacher Gustav Herglotz”
2006 01 10, D. Fenster: “Emil Artin in America: An Overview”
2006 01 10, J. Schwermer: “Beyond Class Field Theory - Different Trajectories in the 1930’s and 1940’s”
2006 01 12, E. Lapid: “Periods of automorphic forms I”
2006 01 12, J. Nekovàř: “Parity of ranks of Selmer groups associated to Hilbert modular forms”
2006 01 17, D. Jiang: “On the Fundamental L-functions of Odd Special Orthogonal Groups”
2006 01 17, W. Müller: “On limit multiplicities of cusp forms”
2006 01 19, E. Lapid: “Periods of automorphic forms II”
2006 01 19, S. Kudla: “Arithmetic Geometry and Fourier coefficients”
2006 01 30, R. Zweimüller: “Asymptotic orbit complexity of infinite measure preserving transformations”
2006 02 01, A. Joyce: “Semi-stable models of modular curves”
2006 02 01, T. Berger: “Eisenstein cohomology and Selmer groups for imaginary quadratic fields”
2006 02 02, G. Gotsbacher: “Eisenstein cohomology classes for SO(n,2)”
2006 02 07, G. Harder: “The constant term of Eisenstein cohomology classes - arithmetic information”
2006 02 07, J. Kramer: “Elliptic Eisenstein series”
2006 02 07, M. Harris: “Theta correspondence, period relations, and special values of L-functions”
2006 02 09, G. Henniart: “Recent progress on the Jacquet-Langlands correspondence”
2006 02 13, S. Müller-Stach: “Shimura curves on Shimura surfaces”
2006 02 16, M. Choda: “Entropy and the Haagerup invariant related to groups with amenable actions”
2006 02 23, A. Papadopoulos: “Generalized metrics”
2006 03 02, T. Monteil: “Finite blocking property in polygonal billiards and translation surfaces”
2006 03 03, H. Derksen: “A Skolem-Mahler-Lech Theorem in positive characteristic”
2006 03 03, U. Zannier: “Some results on integral points for P2 minus a variety in the function field case”
2006 03 09, G. Greschonig: “Regularity of topological cocycles”
2006 03 10, N. Ratazzi: “Zero estimates and Seshadri constants”
2006 03 10, P. Habegger: “Multiplicative dependence and isolation”
2006 03 14, J. Thunder: “Counting Subspaces of Given Height Defined over a Function Field”
2006 03 14, P. Philippon: “Uniform bounds for the number of rational points on certain curves”
2006 03 17, F. Amoroso: “Lower bounds for the height and size of the class group”
2006 03 17, G. Rémond: “On the number of rational points on curves”
2006 03 21, N. Hirata-Kohno: “Number of solutions to unit equations in two variables”
2006 03 21, S. David: “Heights on elliptic curves”
2006 03 23, P. Diaconis: “Mathematics and Magic Tricks”
2006 03 24, C. Pontreau: “Small points on surfaces”
2006 03 24, W. Zudilin: “Effective lower bounds for $\|(N+1)/N)^k\|$”
2006 03 28, J. Vaaler: “An ABC inequality for Mahler’s measure”

2006 03 28, T. Shorey: “Prime divisors of products in arithmetic progression”
2006 03 31, N. Hitchin: “The Geometry of G2”
2006 04 06, R. Miles: “Periodic Point Data and Expansive Subdynamics”
2006 04 07, J. Evertse: “Pairs of binary forms with given resultants”
2006 04 07, K. Györy: “Polynomial powers and binomial Thue equations”
2006 04 07, Y. Bugeaud: “Transcendental continued fractions “
2006 04 11, A. Galateau: “The Bogomolov problem on a product of elliptic curves”
2006 04 11, D. Bertrand: “Some remarks on the functional Schanuel conjecture”
2006 04 11, P. Corvaja: “Greatest prime factor of Markov pairs and integral points on surfaces”
2006 04 20, T. Monteil: “Estimating the number of ergodic measures of a minimal subshift knowing the geometry of its Rauzy graphs”
2006 04 25, D. Roy: “Simultaneous rational approximations to a real number, its square and its cube”
2006 04 26, M. Laurent: “Exponents of diophantine approximation in dimension two”
2006 04 26, M. Waldschmidt: “Survey of some recent results on the complexity of expansions of algebraic numbers”
2006 05 02, C. Stewart: “Heights of multiplicatively dependent numbers”
2006 05 02, Y. Kunrui: “Bounds for the solutions of S-unit equations and decomposable form equations”
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ACM = Advisory Committee Meeting
AGX = Gerbes, Groupoids and Quantum Field Theory
AVW = Quantum Statistics
BKS = Aspects of Spectral Theory
BOL = Boltzmann Symposium
CAP = Guest of Prof. Čap
CEG = Causes of Ecological and Genetic Diversity
CEL = Complex Quantum and Classical Systems and Effective Equations
EU = EU Network Meeting
FGB = Modern Methods of Time-Frequency Analysis
HSU = Complex Analysis, Operator Theory and Applications to Mathematical Physics
JF = Junior Fellow
KKS = Homological Mirror Symmetry
KRS = Arithmetic Algebraic Geometry
MS = Diophantine Approximation and Heights
NBF = Global Optimization
RDSES = Workshop on Discrete Probability
SAS = Rigidity and Flexibility
SCH = Guest of Prof. Schmidt
SCHW = Guest of Prof. Schwermer
SF = Senior Research Fellow
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