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

Boltzmanngasse 9/2
A-1090 Vienna, Austria

Scientific Report for the years 1993 – 2002

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Introduction

A preface by the President

The Erwin Schrödinger International Institute of mathematical Physics (ESI) celebrates its 10th anniversary in the year 2003, the official date for the opening of the Institute being April 20, 1993. The three years preceding 1993 had been a period of intensive preparation in which many people, both Austrian mathematicians and physicists and international colleagues, were involved. The history of this foundational phase is summarized in an Appendix to this report, which includes also several original documents. In the first three years of its existence the Institute was housed in three flats in Pasteurgasse 4–6 in Vienna, in the very building in which Schrödinger had lived during his last years, but in July 1996 it moved to its present premises in Boltzmanngasse 9.

From the outset the mission of the Institute has been to promote research in mathematical physics and mathematics at the highest international level, with particular emphasis on creative interactions between mathematicians and physicists. The geographical location of the Institute in Central Europe has also made it a natural meeting place to stimulate intellectual exchange between scientists from Eastern Europe and the rest of the world.

The usual operational mode of the Institute is to host 5–6 thematic programs each year, covering a wide range of topics in mathematics and mathematical physics. The Institute does not have permanent scientific faculty, but the programs are organized by leading international experts that have submitted a proposal accepted by the International Scientific Advisory Committee of the Institute two years in advance. Each program has as a rule at least one co-organizer from the Austrian scientific community. In the ten years of the operation of the Institute 50 programs have been run at the Institute, involving about 30 Austrian scientists as (co-)organizers. Besides these programs, smaller workshops and conferences take place regularly. A number of visitors also come for varying periods outside of the program and conference activities. Altogether the number of visiting scientists to date is more than 2000 (with more than 3000 individual visits), and they have contributed almost 1300 preprints to the preprint server of the Institute. An assessment of the publication record of these preprints in refereed journals can be found on page 165 of this report.

The bulk of this report is a compilation of the yearly scientific reports of the Institute for the years 1992–2002. It also contains the list of preprints, ordered by date (Appendix B), and an alphabetical list of all visitors to the Institute (Appendix C). Before the Institute was formally opened there were two activities of the projected institute that are also included, a conference on Interfaces between Mathematics and Physics, and a conference to commemorate 75 Years of the Radon Transform. The reports on the individual scientific programs were written by the program organizers. Hence the style of the presentations may vary from one program to another, but together they document the vigor and the broad scope of the activities at ESI during the past 10 years.

There is no doubt in my mind that the Erwin Schrödinger Institute has lived up to the high hopes of its founders. It has given large impetus to research in Austria, both in mathematics and physics, leading to many research cooperations between Austrian and international scientists that would not have been possible within the frame of conventional university institutes and research grants. The numerous seminar talks by international experts at the Institute are also an invaluable source of information for the Austrian scientific community and not least for Austrian graduate students.

The importance of the Erwin Schrödinger Institute for the international scientific community is witnessed by the high quality of the program proposals submitted, which in recent years have exceeded the capacity of ESI by a factor of two, the large number of leading experts in various fields that visit ESI regularly, and the number of high quality preprints contributed by our visitors as a result of their work at the Institute. The unbureaucratic organizational structure and administration and the stimulating working environment have made ESI a highly appreciated meeting place of scientists from many countries.

I feel confident that a large number of both Austrian and international colleagues will join me in the wish that the Erwin Schrödinger Institute may thrive and prosper in the future.

Jakob Yngvason
President of ESI
March 2003

ESI and the Austrian scientific community

Since its foundation in 1993, the Erwin Schrödinger Institute has changed the landscape of research in mathematics and mathematical physics in Austria. It has stimulated interaction between Austrian scientists and their colleagues abroad by providing a platform for collaboration and exchanges of ideas not only in scientific programs and workshops organized well in advance, but also through supporting visitors or small workshops at short notice via the 'Directors Shares' available to the President and the Scientific Directors of the Institute (as explained on the next page, this is the source from which most of the 'Visitors outside the main programs' and some of the 'Workshops outside the main programs' appearing in the Scientific Report are funded). It has also played a considerable role in helping to fill vacant positions at the departments of mathematics and mathematical physics at the University of Vienna: my decision to return to Vienna in 1994 was very greatly influenced by the opportunities offered by the Erwin Schrödinger Institute, and the same is true for several of my colleagues appointed to senior positions in the mathematical sciences in Vienna in recent years. The Institute is also instrumental in attracting excellent foreign post-docs to Vienna.

In order to increase further the impact of the Institute's activities of the on the research, doctorate and post-doc programs of the surrounding universities the Erwin Schrödinger Institute started to introduce in the year 2000 several *Senior Research Fellowships* with the aim of attracting top quality scientists to Vienna for longer (and repeated) periods. The initial response was very encouraging with appointments of S.G. Dani, Yu.A. Neretin, V. Popov, I. Todorov, A. Vershik and others — I refer to the scientific reports for the years 2000 and 2001 for details. In 2001 it became clear, however, that our present budget would not allows us to continue this program at a reasonable level, and for 2001 – 2002 we had to cut back on the number and durations of the invitations (the need for this cut-back was necessitated by the non-appearance of the necessary additional government funding).

In recent discussions with the *Rektoren* of the University of Vienna and the Technical University of Vienna, Professors Winckler and Skalicky, the possibility of reviving and extending the Senior Research Fellows Program as a component in the development of an internationally attractive *Advanced Graduate Program* of the two universities emerged. The ideas put forward on this were sufficiently attractive to the Austrian Government to promise the Institute *in writing* additional funding for this purpose. As a first step towards the realization of this program, the support provided by the University of Vienna in 2002 has enabled us to offer the first two Advanced Graduate Lecture Courses by Senior Research Fellows in the autumn of that year.

Our attempts to maintain and raise further the scientific standard of the Institute can only succeed with the help of the international scientific community. I hope that this report will encourage its readers to assist us in this objective.

In November 2002 the Erwin Schrödinger Institute underwent a thorough evaluation of its scientific activities and the ensuing benefits for the Austrian research communities in mathematics and mathematical physics. After consultation with the Federal Ministry of Education, Science and Culture, it was decided to follow a review procedure modelled on that used by the Austrian Academy of Sciences in recent years. Professor J.-P. Bourguignon, director of IHES in Bures-sur-Yvette, selected an independent review panel of 5 leading scientists and appointed its chairman, Professor Nigel J. Hitchin, Oxford. The report by the review panel is attached on page 141ff.

Finally I would like to express my gratitude both for the political vision of ex-minister Dr. E. Busek and the enthusiasm and effort of the scientific founders of the Institute, Walter Thirring and Peter Michor, which together made this genuine miracle possible in Austria: a research institute with an uncompromising international outlook, almost completely free of bureaucratic constraints, and able to react quickly and effectively to scientific developments and opportunities.

Klaus Schmidt
Scientific Director
March 2003

About this report

Most items in this report are self-explanatory. However, a few comments are in order.

The scientific report. The reports on the individual programs and workshops are only slightly edited versions of the final reports provided by the organizers of the programs.[1] This results in considerable differences in style and presentation. Many of these programs have 'follow-up activities' in the following years: subject to the budgetary constraints, this allows organizers to use some of their unspent program funds in the following year(s). In terms of scientific productivity, these follow-up events are usually excellent investments: they allow to harvest ideas developed during the main programs which have matured in the meantime.

The numbers in square brackets refer to the ESI Preprint List in **Appendix B.**

At the end of the report for each year there are sections on *Workshops* and *Visitors* outside the main programs. Except where stated otherwise, the funding for these items comes from the *Directors' shares*, which are available to the Scientific Directors and the President, to respond to short-term opportunities for invitations and collaboration, and to provide funds for requests from the resident scientific communities. The total amount of money made available in this form is roughly equivalent to one scientific program.

Report of the Review Panel. The full report (including the composition of the review panel) is attached at the end of the scientific report on on page 141ff.

Appendix A: History. This section contains a short history of the foundation of the Erwin Schrödinger Institute starting on page 151, as well as the main discussion papers and reports which helped to persuade the authorities to fund the Erwin Schrödinger Institute. Although these documents are generally of purely local interest (and are partly in German for obvious reasons), one of them may be of interest to a wider readership: the report on the foundational workshop *Interfaces between Mathematics and Physics* of the Erwin Schrödinger Institute in 1991 on page 155. In spite of its fragmentary form it contains some very interesting views by the participants (including Budinich, Connes, Fröhlich, Faddeev, Galindo, Marmo, Souček, Trautman, Todorov, Vinogradov and Wess) on research and research institutes in the mathematical sciences.

Appendix C: List of Visitors. This appendix starts with a listing of 'codes', i.e. of abbreviations indicating the program(s) or person(s) sponsoring each visitor (and, indeed, each visit). For technical reasons this list does not contain some of the names of visitors during the second half of 2002.

Appendix D: Statistics. This appendix lists the following figures for each year.

1. The total budget, the expenditure on programs and visitors, and the contributions to the ESI science budget from external sources;
2. The number of programs and separate conferences and workshops (co-)organized by ESI;
3. The number of ESI preprints;
4. The numbers of visitors and individual visits, and the average durations of visits;
5. A breakdown of the countries of origin of the visitors.

[1] Except where explicitly stated otherwise, these reports were produced jointly by all organizers of the program.

Part II

Scientific Report

Activities in 1992 preceding the official opening of the Institute

Conference on 'Interfaces between mathematics and physics'

This conference took place during the week March 2–6, 1992 and was the first public activity of the then projected Erwin Schrödinger Institute. Nine lectures were given, two hours each:

A. Connes: Non-commutative Geometry.
L. Faddeev: Involution in Quantum groups and deformed affine algebras.
J. Fröhlich: Gauge Symmetry in Condensed Matter Physics.
K. Gawedzki: Conformal Field Theory and Black Holes.
P. Michor: Gauge theory for the Diffeomorphism Group.
I. Todorov: Conformal Quantum Field Theory.
A. Trautman: Geometric Aspects of Spinors.
A. Vinogradov: Geometry of Partial Differential Equations and Quantized Calculus.
J. Wess: Quantum Groups.

A detailed report on this conference appears on on page 155.

Conference '75 years of Radon transform'

This conference took place during the week August 31 – September 4, 1992, and was organized by S. Gindikin and P. Michor. The proceedings of this conference were published under the title *75 Years of Radon Transform,* eds. S. Gindikin, P. Michor, International Press, Boston MA, 1994.

Program

Plenary lectures:

A. Cormack: The Radon transform: A personal Odyssey.
S. Helgason: Radon transforms for Double Fibrations - Examples and Viewpoints.
E. Stein: Estimates for Radon transform and singular Radon transform.
S. Gindikin: Radon transform from cohomological point of view.
A. Goncharov: Integral geometry and varietes of minimal degree in $\mathbb{CP}(n)$.
G. Beylkin: Inversion of the Generalized Radon Transform and its Applications.
J. Wolf: Uncertainty principles for symmetric spaces.
F. Natterer: Sampling the Radon transform.
E. Hlawka: Uniform distribution and Radon transform.
F. John: Reminiscences.
M. I. Graev: Radon transform and hypergeometric functions.
F. I. Karpelevich: Applications of Radon transform to random processes.

Lectures within workshops:

M. Agranovsky: Radon-Pompeiu transform and CR-functions on the Siegel manifold.
C. Berenstein: Inverse conductivity problems and the hyperbolic Radon transform.
E. Casadio: Radon transform on trees.
F. Gonzales: Range of the Radon transform on Grassmannians.
A. Greenleaf: Microlocal analysis of the two-plane transform.
E. Grinberg: Radon transform for maximally curved spheres.
T. Kobayashi: Bounded domains and the zero set of Fourier transform.
P. Kuchment: On the range and inversion of a Radon transform arising in tomography.
P. Michor: Curvature and the Radon transform.
G. Mockenhaupt: On the circular maximal function.
K.-H. Neeb: Wiener-Hopf operators on symmetric spaces.

E. Opdam: Properties of Dunkl functions.
D. H. Phong: Models of degenerate Fourier integral operators.
V. Palamodov: Radon transform on real algebraic varieties.
E. T. Quinto: Support theorems for generalized horocycle transforms on higher rank spaces.
F. Richter. Fundamental differential operators and range of the Radon transforms.
V. Soucek: The Penrose transform for the Dirac equation.
A. Zaslavski: The Radon transform of discontinuous functions: Legendre transform, projective dual varieties and envelopes.
L. Zalcman: Morera's theorem, 100 years after.

The year 1993

General remarks

Management of the Institute

President and Scientific Director: Walter Thirring
Acting Director: Peter Michor
Administration: Mario Springnagel, Elisabeth Haffner
Computers: Andreas Čap, Hermann Schichl

International Scientific Advisory Committee

The founding scientific committee of the Institute also became the first Scientific Advisory Committee of ESI. Its composition was as follows:

P. Budinich (Trieste)
A. Connes (IHES)
V. Drinfeld (Kharkov)
L.D. Faddeev (St. Petersburg)
J. Fröhlich (ETH Zürich)
A. Galindo (Madrid)
E. Lieb (Princeton)
G. Marmo (Naples)
H. Narnhofer (Vienna)
V. Souček (Prague)
I.T. Todorov (Sofia)
A. Trautman (Warsaw)
A.M. Vinogradov (Moscow)
J. Wess (Munich)
W. Reiter (Bundesministerium für Wissenschaft und Forschung)

The official opening of the International Erwin Schrödinger Institute for Mathematical Physics (ESI) took place on 20th April 1993, with the Austrian Minister for Science and Research, Vice Chancellor Dr. E. Busek performing the opening ceremony.

The Institute was housed in 3 flats near the Institutes of Mathematics and of Theoretical Physics of the University, in Pasteurgasse 4/7, 6/7, and 6/11, 1090 Wien, with premises encompassing $420m^2$. One of these flats was located just below the last residence of Erwin Schrödinger in Vienna.

Budget and visitors: The budget of ESI for 1993 was ATS 9,5 Mio. (about €690.400). ATS 4,1 Mio. were spent on scientific activities and ATS 5,4 Mio. on administration, infrastructure, and adaptation of the building. Visitors supported from external (mainly non-Austrian) sources contributed the equivalent of a further ATS 400.000.

The number of scientists visiting the Erwin Schrödinger Institute in 1993 was 103, and the number of preprints was 67.

Programs in 1993

Two dimensional quantum field theory

Organizer: H. Grosse

Total budget (including follow-up activities): ATS 1,46 Mio.

Preprints contributed: [69], [71], [77], [79], [80], [82], [90], [91], [95], [105], [110], [113], [118], [121], [132], [143], [214], [217], [225], [233], [234], [244].

Report on the program

This program focussed on three main subjects:

Integrable models, lattice spin models and magnetic field models. Integrable Models can be obtained through solutions of the Yang-Baxter relation. An infinite number of conserved quantities show up, and the transfer matrix can be diagonalized with the help of the algebraic Bethe Ansatz. This way it is possible to study the phase diagram of the model. All three contributions from Borovick [12], [13], [66], are of this type. In [12], vertex models defined on two layers which interact with each other are treated; in [13] and [66] integrable multicomponent models are dealt with. In Pasquier's paper [24], a Calogero-Sutherland model with spin is treated. Properties like degeneracies of the spectrum have been derived from a solution of the Yang-Baxter relation and from the underlying Yangian symmetry. In my work with Raschhofer [26] we treated an $SU(3)$ type XXZ model which is also integrable; we were able to obtain the finite size corrections and determined the conformal charge which turned out to depend on the interaction. Although the 1-dimensional Hubbard model is integrable also, it is the 2-dimensional one which is the favorite model to explain super conductivity, which up until now has only been analyzed through approximate methods. A careful self-consistent mean field type analysis of the appearance of antiferromagnetic, ferromagnetic as well as superconducting phases, is given in the papers [31], [77], by Popov. Van Hove points play an essential role thereby.

In a common work with Popov [57], we found a way to relate the partition function of general spin systems to partition functions of fermion systems. For the latter, standard expansion methods can be applied. Spectra of Magnetic field problems are of interest, due to our interest in the quantum Hall effect. How the degenerate spectra of Landau levels split under the influence of nonconstant magnetic fields as well as under the influence of scalar potentials is analyzed in a common work together with Stubbe [71].

Models of quantum field theory – external field problems. One of my own interests concerns cocycles which occur as central extensions of current algebra and the Virasoro algebra. They can be studied in external field problems within quasi-free second quantization. Together with Maderner and Reitberger, [8], we formulated these Schwinger terms as cyclic cocycles, respectively characters of a 2-summable Fredholm module. General states have been treated, and especially the independence of these cocycles on temperature has been formulated. We studied, in addition, anomalies between generators of translation and time evolution, within spin models for Kink-like states [22]. We compare our way of implementing the generators in finite temperature states to another method, which allows us to obtain temperature dependent anomalies. A further way to define symmetry generators for noncyclic states, together with a summary of the various approaches is given in [59]. Together with Maderner, we analyzed the classical origin of the fermionic Schwinger term in [58]. It turned out that the comomentum mapping is not a homomorphism of Lie algebras, and the algebra of charges can be recovered in an entirely classical context of smooth functions on the Grassmanian.

Algebraic theories.

1. **Chern-Simons model.** In discussions with Alekseev and Schomerus, we made attempts to obtain a lattice model which enjoys as a gauge symmetry, a quantum group. We therefore studied a lattice version of the Chern-Simons model. What results is a mathematically precise quantization of the

Hamiltonian Chern-Simons model. We constructed the algebra of observables and formulated the model such that the lattice version already reproduces the results of the continuum model exactly.

2. **Conformal field theory.** This lively expanding subject was well represented by the Bulgarian group. Their method of obtaining local extensions of the chiral algebra of observables for conformal invariant models led to Stanev's publication [19]. He constructs all such extensions with the help of polynomial solutions of the Knizhnik-Zamolodchikov equation for SU_3 current algebra at level k. Discussions at ESI, between the Bulgarian and the Hamburg group, led to the understanding that there exist local extensions of the algebra of observables, which do not belong to the class considered by Doplicher-Haag-Roberts. A summary of 'What we are learning from 2-dimensional conformal models?' is given by Todorov in his Beer Sheva Workshop contribution [52].

3. **Noncommutative manifolds.** In my own attempts to relate models of QFT to noncommutative geometry, we studied, together with Prešnajder, the noncommutative analogs of homogeneous spaces using coherent states [23]. A one parameter family of algebras is obtained, which yields in the commutative limit the algebra of functions over a standard manifold. We apply this procedure to the Fuzzy sphere and to the Fuzzy hyperboloid. In a further contribution, we formulate the noncommutative analog of the Dirac operator on these algebras and find its spectra. This allows us to describe the analogs of the Thirring model in this noncommutative lattice.

4. **Quantum groups.** Quantum Groups are, in a way, the central algebraic structure, which came out from studies of integrable models. This was also reflected in a number of seminars dealing with this new algebraic concept and also in a number of contributions.

   Hadjiivanov studied the q-deformation of Bose parastatistics [20], and obtained a deformation of the algebra of para Bose-oscillators. The dynamics of a point particle moving on a 3-sphere was considered by Stanev and Todorov in [34]. They used an R-matrix which depends on a time parameter. It led to interesting discussions with the Hamburg group and might lead to a new concept: quasi Yang-Baxter equation for an R-matrix depending on a spectral parameter. Together with Prešnajder [45], we considered the classification of unitary representations of the q-oscillator algebra and showed the connection to explicitly known realizations.

   The duality between deformations of the algebra of functions over a group to the deformations of the universal enveloping algebra of the Lie algebra, is worked out for Z_2-graded Hopf algebras by Pittner [69]. In the classical limit an interesting algebraic structure results.

   Rehren worked out possible values which the index of subfactors can take in [14].

5. **Poisson structures.** Perelomov [17] joined visitors from the mathematics programme (Grabowski and Marmo), and worked out a classification of all possible Poisson structures in low dimensions.

   The publication [33] by Alekseev and Todorov would not have been possible without the opportunity to combine the experience of Fadeev's group in St. Petersburg on quadratic brackets and Lie-Poisson groups, with the experience of the group in Sofia on matching the monodromy of chiral sector solutions of the Knizhnik-Zamolodchikov equation with a certain quantum group monodromy.

List of participants.

Longer term visitors

I. Todorov, Inst. f. Nucl. Research, Sofia, Bulgaria 15.2.-15.5.
V.N. Popov, Steklov Math. Inst., St. Petersburg, Russia 1.4.–30.6.
A.E. Borovick, Kharkov, Ukraine, 1.3.-31.3.
A. Perelomov, Univ. Bonn, 1.3.-15.3.
A. Alekseev, Dep. of Math. Physics St. Petersburg, Russia, 1.3.-30.6.
V. Schomerus, Univ. Hamburg, 1.3.-31.8.
L. Hadjiivanov, Inst. f. Nucl. Research, Sofia, Bulgaria, 15.2.-15.5.
V. Stanev, Inst. f. Nucl. Research, Sofia, Bulgaria, 15.2.-15.5.
K. Gawedzi, IHES Bures-sur-Yvette, 1.3.–31.3.
G. Mack, Univ. Hamburg, 3.5.–28.5.
K.H. Rehren, Univ. Hamburg, 1.3.–31.3.

K. Fredenhagen, Univ. Hamburg 15.2.–10.3.
V. Pasquier, Saclay, Paris, 1.3.–31.3.
P. Presnajder, Univ. Bratislava 1.6.–31.6.

Short invitations were issued to M. Havlicek (Prag), V. Rittenberg (Bonn), J. Madore (Orsay), R. Flume (Bonn), G. Sotkov (Sofia), A. Schnizer (Tokyo), F. Nill (Berlin) and W. Weich (Munich).

This program included a workshop on *Two dimensional quantum field theory* (March 8–12, 1993) with 120 participants. There were lectures on **quantum field theory** by Todorov, Nahm, Schomerus, Marchetti, Fredenhagen, Rehren, Onofri, Alekseev and Seiler, on **gravity** by Jackiw, Presnajder and Kummer, on **integrable models** by Pasquier, Mussardo and Faddeev, on **Chern-Simons and topological quantum field theory** by Karowski, Itzykson and Gawedski, and on **noncommutative differential geometry** by Fröhlich, Dubois-Violette and Madore. In addition to these main lectures there were shorter contributions on **quantum groups** and **gravity**.

Continuation of the program in 1994. After the development of quantum mechanics the line spectra of atoms and molecules, the periodic system as well as macroscopic properties of condensed matter have been explained. Although the quantum mechanics of atoms and molecules is well understood, the many-body effects offer, on the contrary, new challenging problems. The most prominent recent examples are high Tc superconductivity materials as well as the recent discovered quantum Hall effect. (To both subjects a Nobel prize has been awarded). Models describing these phenomena have been dealt with in our program. Various properties of spin systems related to superconductivity have been analyzed. The new technique of almost solvable models has been applied. Within the description of the quantum Hall effect geometrical and analytical methods have to be combined. It was a great surprise, when it was first observed experimentally, that the Hall conductivity at low temperatures and at high magnetic fields shows flat plateaus in 2-dimensional structures at well-described values of the filling factor. Models explaining the so-called fractional effect are still under debate. The precision of the plateaus compares with the most accurate measurements in nature.

The third kind of models dealt with in that program describes conductivity along one-dimensional systems, so called quantum wires. There exist new experimental methods in semiconductor technology, which allow to prepare almost one dimensional structures. Within the new subject, which is called mesoscopic physics, a number of elder ideas of quantum mechanics have been experimentally verified.

Continuation of the program in 1995. The lively developments in this field were reflected also in the continuation of this programme (which started in 1993 and had a continuation a small scale in 1994). This time altogether ten visitors spent around two to four weeks at ESI.

The main subjects treated were Integrable Lattice Spin Models and Quantum Groups (Faddeev, Scheunert, Jurco, Kulish), Conformal Quantum Field Theory (Todorov, Niemi, Wipf) and Noncommutative Geometry (Coquereaux, Presnajder). For all three subjects, papers were delivered and seminars held. Some papers are still in preparation. During a one-day visit, Kuchar reported on the latest news concerning the Quantum Hall effect.

Quantum groups are still of great interest, and the recent developments around the reflection equation and applications to q-deformed Minkowski spaces were treated. The problem of quantizing the Liouville equation has been dealt with also.

New soluble models of conformal quantum field theory are obtained through the study of the Khizhnik-Zamolodchikov equation. Various versions of the WZNW-model led to a publication by the Bulgarian group.

We used the ideas of noncommutative geometry to obtain a cut-off procedure for quantum field theory. Scalar fields, gauge fields and spinor fields in two dimensions can be handled. Most surprisingly our method allows to handle supersymmetry without breaking it.

After finishing this project it is a pleasure for me to thank all people involved (visitors and staff) for providing an excellent atmosphere, so that scientific exchange on this high level was possible. Since four of our guests lectured this year also at the Schladming Winter School, the whole Austrian physics community, as well as 140 participants profited from the activity in Vienna.

Schrödinger operators

Organizer: T. Hofmann-Ostenhof

Total budget (including follow-up activities): ESI: ATS 1,61 Mio., external sources: ATS 70.000.

Preprints contributed: [71], [74], [75], [78], [99], [100], [124], [137], [139], [151], [152], [155], [160], [161], [162], [180], [181], [182], [184], [190], [193], [262], [208], [211], [212], [237], [238], [249], [250], [258], [262], [263].

Report on the program

For over 65 years quantum mechanics and hence the Schrödinger equation has played a central rôle in the description and understanding of nature, in particular atoms and molecules. The questions raised and the answers given by quantum mechanics has led to many far reaching new developments not only in physics, but also in chemistry, mathematics and even philosophy.

There has always been a strong mutual influence between quantum mechanics and mathematics. Quantum mechanics prompted, even as early as in the 1930's, the development of some new areas in mathematics like the functional analysis of unbounded operators, and influenced with its new problems, many other fields of mathematics (representation theory, C^* algebras etc). On the other hand, new developments in various fields in mathematics (e.g. partial differential equations, stochastic processes, pseudo differential operators etc), have played, and still play an increasingly important rôle in the progress in quantum physics, and especially in the investigation of the Schrödinger equation, leading us to a better understanding of this important part of physics.

The Schrödinger equation is a partial differential equation. The central objects one deals with are called 'Schrödinger operators'. Ever since the end of the 1960's, 'Schrödinger operators' is a very active field in mathematical physics and mathematics, with many probing results, and, naturally enough, still many open, challenging problems.

The programme 'Schrödinger operators' was devoted to such problems. It started in spring and culminated at the beginning of December in a workshop with about 50 participants. Approximately 25 scientists visited the ESI during the year. 25 seminar talks and 37 talks at the workshop were given. The list of the talks, visitors etc. can be found below.

The research activities were devoted to the spectral theory of elliptic operators [27], [29], [43], [62], [64], [67], [71], [74], [75], to scattering theory [60], [63], and to properties of the solutions of Schrödinger equations [35], [36]. Schrödinger operators with magnetic fields were investigated very intensively and very successfully [27], [67], [71], [74], [75]. The analysis of Schrödinger operators with magnetic fields poses many new, physically important and challenging problems. Collaborations on such problems have been started and were subsequently continued in the near future at ESI. Also other questions concerning the spectral theory of Schrödinger operators and scattering theory, as well as the Schrödinger equation considered as a partial differential equation, led to collaborations which were continued at ESI. The seminar talks were especially helpful in starting the exchange of ideas and discussions between the visiting scientists and some Austrian colleagues, but in particular between scientists from former Eastern Bloc countries and scientists from the West.

Naturally, a programme of this size could not cover the enormously rich field of Schrödinger operators, and therefore had to focus around some specific problems. But the talks given at the workshop documented very well the progress made in other fields related to Schrödinger operators — in spectral geometry, microlocal analysis, time dependent problems etc.

Finally, I should like to mention that the accommodation for the scientists, their salaries, and the sometimes difficult visa problems, was handled smoothly and efficiently by Mr. Springnagel, and the handwritten manuscripts were brought into their final form competently by Miss Haffner. The good working atmosphere led to many interesting contacts with scientists participating in other programmes and was nourished by the cooperative efforts of Professor Michor, Professor Thirring and other Viennese colleagues. All these individuals I want to thank heartily.

List of participants in 1993

Bach, Volker, TU Berlin, 11.10.-24.10.93
Combes, Jean Michel, University of Toulon, 22.11.-16.12.93
Derezinski, Jan, University of Warsaw, 22.9.-21.12.93
Erdös, Laszlo, Princeton University, 28.11.-18.12.93
Exner, Pavel, Nuclear Institute Prague, 18.10-12.12.93
Gerard, Christian, Ecole Polytechnique Palaiseau, 18.10.-29.10.93
Graf, Gian Michele, ETH Zürich, 11.10.-22.10.93
Harrell, Evans, University of Atlanta, 22.11.-17.12.93
Hempel, Rainer, University of Alabama, 4.12.-18.12.93
Herbst, Ira, University of Virginia, 1.6.-30.06.93
Hislop, Peter, University of Kentucky, 07.12.-20.12.93
Ivrii, Victor, University of Toronto, short visitor (December'93)
Kalf, Hubert, University of Munich, 26.09.-10.10.93
Karner, G. University of Virginia, short visit (June'93)
Korotyaev, Evgeni, Electrotechnical University of St. Petersburg, short visitor (December'93)
Loss, Michael, Georgia Technical School of Mathematics, 20.09.-20.12.93
Nadirashvili, Nicolai, University of Moscow, 01.03.-13.07.93
Nenciu, Gheorghe, University of Bucharest, 01.10.-31.12.93
Pavlov, Boris, University of St. Petersburg, 31.10.-19.12.93
Siedentop Heinz, University of Trondheim, 19.06.-02.07.93, 01.12.-16.12.93
I.M. Sigal, University of Toronto, January'93 (short visitor)
Skriganov, Maxim, University of St. Petersburg, 05.12.-19.12.93
Sobolev, Alexander, University of Nantes, 30.11.-12.12.93
Stubbe, Joachim, CERN Geneva, 11.10.-29.10.93
Thaller, Bernd, University of Graz, 11.11.-13.12.93
Vugalter, Simeon, Radiophysik Institute, Nishni Nogorod, 19.10.-19.12.93
Yafaev, Dimitri, University of Rennes, 30.09.-30.10.93, 29.11.-19.12.93
Zhislin, Gregory, Radiophysik Institute, Nishni Nogorod, 15.11.-15.12.93

Workshop on Schrödinger operators.

Program

M. S. Birman (St. Petersburg): A perturbation of a periodic Schrödinger operator by a modulated decaying potential.
M. Bordoni (Rome): A method to compare operators. Applications to Schrödinger and Dirac operators.
Y. Colin de Verdiere (Grenoble): Semi-classical analysis of tunneling and graph's embedding into surfaces.
J. M. Combes (Toulon): Positive commutators and perturbation of the singular spectrum.
M. Combescure (Paris): Localization versus diffusion for 'kicked' quantum systems.
M. Demuth (Potsdam): Trace class criteria in stochastic spectral analysis.
J. Derezinski (Warsaw): Long-range scattering theory for time-dependent potentials.
P. Exner (Prague): Wannier-Stark ladder with unusual spectral properties.
L. Erdös (Princeton): Magnetic Lieb-Thirring inequalities.
G. Goldstein (Baton Rouge): Spin polarized Thomas-Fermi theory with the Fermi-Amaldi correction.
J. Goldstein (Baton Rouge): Obstacle scattering for elastic waves.
E. Harrell (Atlanta): Some bounds on eigenvalues and spectral gaps of Schrödinger and Laplace operators.
B. Helffer (Paris): On the Schrödinger equation in large dimensions.
R. Hempel (Birmingham, USA): Strong magnetic fields, Dirichlet boundaries, and spectral gaps.
A. Hinz (Munich): Selfadjointness of Schrödinger operators.
P. Hislop (Lexington, USA): Localization for the scalar wave and Maxwell equations in random medias.
M. Hoffmann-Ostenhof (Vienna): Regularity properties of the zero set of solutions to Schrödinger equations.
V. Ivrii (Toronto): Accurate spectral asymptotics for operators with singularities and the Scott correction term.
G. E. Karadzhov (Sofia): Spectral asymptotics for some Schrödinger operators and applications.
E. Korotyaev (St. Petersburg): The effective masses and conformal mapping.
Y. Kuperin (St. Petersburg): Adiabatic Faddeev equations for three-body quantum scattering.
M. Loss (Atlanta): Fluxes, Laplacians and Kasteleyn's theorem.
A. Martinez (Paris): Non-linear Stark effect and molecular localization.
E. Mitidieri (Trieste): Weakly coupled elliptic systems and positivity.
G. Nenciu (Bucharest): Perturbation theory for time dependent Hamiltonians.
H. Neidhardt (Berlin): On the Spectra of self adjoint extensions.
B. Pavlov (St. Petersburg): Harmonic analysis on Riemann surfaces and the Lax-Philipps theory for lattices.
D. Robert (Nantes): Statistics of level spacings and distributions of matrix elements for chaotic systems.
R. Seiler (Berlin): Charge transport and the index of projectors.
H. Siedentop (Oslo): Electronic densities of large atoms near the nucleus.
M. Skriganov (St. Petersburg): Anomalies in spectral asymptotics.
A. V. Sobolev (Nantes): The precise asymptotics for the discrete spectrum of the Schrödinger operator with Coulomb singularities in a homogeneous magnetic field.
J. Stubbe (Geneva): A sum rule for the Schrödinger equation and applications.

S. Vugal'ter (Nizhni Novgorod): Limits on stability of positive molecular ions in a homogeneous magnetic field.
D. Yafaev (Rennes): Eigenfunctions of the continuous spectrum for the N-particle Schrödinger operator.
G. Zhislin (Nizhni Novgorod): On the localization of the essential spectrum of N-particle Hamiltonians with magnetic field

Amongst the participants of the conference not contributing a talk were: B. Baumgartner (Vienna), P. Clement (Delft), M. Daumer (Munich), H. Grosse (Vienna), H. Kalf (Munich), P. Michor (Vienna), H. Narnhofer (Vienna), Walter Thirring (Vienna), and a few other Austrian colleagues.

Continuation in 1994. The activity in Schrödinger operators in 1994 was mainly the continuation of the 1993 program. It was more specialized in the sense that the problem of understanding Schrödinger operators with magnetic fields was the central topic to which about half of the activity was devoted. Consideration of magnetic Hamiltonians lead to new and challenging problems and many of the questions which have been answered satisfactorily for operators without magnetic fields await still answers for the case with magnetic fields.

There were 15 visitors, 20 preprints were written, 10 of which were devoted to the magnetic case ([71], [74], [75], [78], [155], [162], [180], [181], [182], [184]). These works address problems in solid state physics ([74], [155], [162]) spectral theory ([71], [75], [78], [180], [181]) and properties of magnetic eigenfunctions ([184]).

The other work includes scattering theory ([100], [139]) spectral theory ([124], [137]) inverse spectral theory ([151], [152], [161]) and properties of solutions of Schrödinger operators ([99]). With some ideas stemming from Schrödinger operators techniques a problem in hydrodynamics was solved ([160]).

Perhaps I should mention the work of Hempel and Herbst on the Hamiltonians without potential but with special magnetic fields which give rise to spectral behavior typical for solids (band structure), ([74] and [162]). Fefferman and Seco considered the spin of a large atom in its ground state ([137]) and Nadirashvili et al. consider the regularity of the zeros of solutions to Schrödinger equations ([99]).

There were many seminars given about various topics, I just want to mention two interesting seminars on Ginzburg Landau models by Loss and by Struwe as well as a seminar on resonances given by Agmon.

Finally I should remark that some of the preprints produced during the activity in 93 already appeared or are about to appear. For instance the seminal result of N. Nadirashvili ([29]) who proved a 115 year old conjecture of Lord Raleigh concerning the fundamental frequency of vibrating plates is about to appear in Archive of Rational Mathematics.

Differential geometry

Organizer: P. Michor

Total budget (including follow-up activities): ESI: ATS 2 Mio., external sources: ATS 850.000.

Preprints contributed: [1], [2], [4], [5], [6], [7], [9], [10], [11], [15], [16], [17], [21], [26], [28], [30], [32], [37], [38], [39], [40], [41], [44], [46], [47], [48], [49], [50], [51], [53], [54], [55], [56], [61], [65], [66], [68], [70], [72], [73].

Report on the program

The field of differential geometry has a long tradition of mutual scientific exchange with theoretical physics, and this exchange is even growing in importance now. Thus it fitted well into ESI as a mathematical program.

The following topics were worked on:

1. Classical mechanics: here G. Marmo coordinated the discussion, G. Vilasi, G. Landi, J. Grabowski, D. Alekseevski, A. Perelomov (from 2-dim. QF program), T. Ratiu, I. Vaisman, A. Vinogradov and others contributed. Preprints [2], [5], [16], [17], [26], [28], [40], [46], [49], [66], [70], [72], [73] belong to this field.

2. Geometry of nonlinear partial differential equations: A. Vinogradov coordinated this activity, A. Vinogradov, V. Lychagin, I. S. Krashilchik, V. V. Sokolov, V. N. Chetverikov. Preprints [9], [46], [47], [48], [51], [53], [54], [55], [61], [73].

3. Infinite dimensional differential geometry: Here a topical series of lectures by D. Burghelea on Waldhausen algebraic K-theory and cohomology of diffeomorphism groups was held in July. Preprints [4], [11], [26], [41].

4. Riemannian differential geometry and related material: Here D. Alekseevski was most active, preprints [7], [11], [21], [30], [32], [38], [39], [65], [70].

5. Spectral theory on manifolds. Here was some collaboration with the program on Schrödinger operators. D. Burghelea, L. Friedlander, F. Kamber, were active here, preprints [37], [44], [65].

List of visiting scientists

D. Alekseevki, Center 'Sophus Lie', Moscow, January 18 -July 10,
Bogdan Bucicovschi, Columbus, July 14–July 31,
D. Burghelea, Columbus, June 14 – August 14,
Pierre Cartier, IHES, 10 days, April 14–24,
Vladimir N. Chetverikov, Moscow, September,
L. Friedlander, Arizona, July 5 – July 31,
Thomas Friedrich, Humboldt Universität, June 19–25,
Olga Gil-Medrano, Valencia, March 15–20, supported by Spain,
Janusz Grabowski, Warsaw, 4 months, February 15 – July 14,
Dmitri Gurevich, MPI Bonn, Moscow, April 4–9,
Franz Kamber, University of Illinois at Urbana-Champaign, July,
Max Karoubi, Paris VII, April 21–24,
I. S. Krashilchik, Moscow, September – October,
Gianni Landi, SISSA, Trieste, January 17 – July 17, supported by Italy,
Fedele Lizzi, Napoli, April 4 – May 7, supported by Italy,
M. Losik, Saratov, Russia, June – July,
V. Lychagin, Center 'Sophus Lie', Moscow, September – October,
M. Markl, Czech Academy of Sciences, June 11 – July 6,
G. Marmo, Napoli, January 17 - May 20,
Giovanna Mendella, Napoli, February 20–24, supported by Italy,
Giuseppe Morandi, Bologna, February 5–12; supported by Italy
A. L. Oniscik, Moscow, January 10–April 10,
Emanuela Nicorestianu, Technical University Bucarest, May 20 – June 20, supported by an Austrian scholarship,
I. Penkov, University of California, Riverside, September – October,
T. Ratiu, University of California, Santa Cruz, June 21 – July 24,
S.M. Salamon, Oxford, June 20–27,
Gaetano Scarpetta, Salerno, March 7– 13, supported by Italy,
Rudolf Schmid, Emory University, Atlanta, June 24–July 23,
Steven Shnider, Bar-Ilan, June 24–30, supported by Israel,
V. V. Sokolov, September – October,
Giovanni Sparano, Napoli, February 24 – March 16, supported by Italy,
Andrea Spiro, Ancona, April 4 – 9, supported by Italy,
Wlodizimierz Tulczyjew, Camerino, April 13 – 20; supported by Italy,
I. Vaisman, Haifa, July 20 – September 15,
J. Vanžura, Brno, September,
Gaetano Vilasi, Salerno, January 18 – February 14 and March 7 – April 7, supported by Italy,
A. Vinogradov, Salerno, Jan. 18 – March 19, and July 15– October 15,
Patrizia Vitale, Napoli, April 18 – May 7, supported by Italy,
Cornelia Vizman, Timişoara, May 20 – December 20, supported by an Austrian scholarship.

Continuation of the program in 1994. A good part of the available resources were devoted to invite D. Alekseevsky, who organized the program on quaternionic manifolds. Some Eastern European Scientists were invited in order to help their research.

There was an intensive collaboration between Michor and M. Dubois-Violette (who visited only 1 week) on the Frölicher-Nijenhuis bracket and non-commutative geometry, see preprints [70], [111], [133]. Preprint [72] on Poisson structures on the cotangent bundle of a Lie group or a principal bundle and

their reductions came out of a collaboration in 1993 at ESI, where some participants did not even know each other before coming to ESI, and it was ignited by a talk by A. Alekseev (preprint [33]). Preprint [73] is an important contribution, connected with the stay of Tudor Ratiu and J. Marsden, another preprint by them is in preparation. Shan Majid contributed preprints [120], [130], [131] on quantum geometry, and he had influence on the preprint [163]. Alekseevsky contributed preprints [72], [138], [150], and some more are in preparation. Izu Vaisman spent one month, worked mainly on Poisson manifolds, and contributed [122], [123]. Perelomov, who was invited jointly with H. Grosse, contributed [143]. D. Juriev spent one month and contributed [167], [170]. From Timisoara I invited M. Craioveanu and M. Puta, who are working in some isolation in Rumania for 6 weeks each, and they contributed [164], [165], [177], and [178], on classical mechanics and Hamiltonian geometry. Altogether there were 29 preprints in this program.

Visitors outside the main programs

ESI spent ATS 400.000, 3 preprints were contributed.

The year 1994

General remarks

Management of the Institute

President and Scientific Director: Walter Thirring
Acting Director: Peter Michor
Administration: Mario Springnagel, Elisabeth Haffner
Computers: Andreas Čap, Hermann Schichl

International Scientific Advisory Committee

P. Budinich (Trieste)
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A. Trautman (Warsaw)
A.M. Vinogradov (Moscow)
J. Wess (Munich)
W. Reiter (Bundesministerium für Wissenschaft und Forschung)

Budget and visitors: The budget of ESI for 1994 was ATS 9,5 Mio. (equivalent to about €694.000). ATS 4,4 Mio. were spent on scientific activities, and ATS 4,8 Mio. on administration and infrastructure. Visitors supported from other sources contributed the equivalent of a further ATS 750.000.

The number of scientists visiting the Erwin Schrödinger Institute in 1994 was 185, and the number of preprints produced was 119.

In 1994, ESI became a founding member of the association 'International Mathematical Sciences Institutes (IMSI)', with Peter Michor attending the founding meeting of IMSI just before the International Congress of Mathematicians in Zürich, August 2, 1994.

After some discussions with visitors of ESI, and after seeing receiving may requests for preprints, it was decided to make available via anonymous FTP the POSTSCRIPT-files of all preprints produced at ESI of which the TeX-files are available, a list of all preprints, the newsletters, and all abstracts in ASCII form. In the year 1994 there were 606 preprints retrieved from this server. The preprints can be retrieved from `http://www.esi.ac.at/preprints`.

Programs in 1994

Ergodicity in non-commutative algebras

Organizer: H. Narnhofer

Total budget: ESI: ATS 600.000, external sources: ATS 100.000.

Preprints contributed: 86], [97], [102], [103], [104], [106], [108], [109], [115], [129], [136], [204], [226], [267], [274].

Report on the program

In the program on noncommutative ergodic theory our purpose was to transfer ideas of classical ergodic theory to dynamics of nonabelian algebras. We concentrated on the concepts of Lyapunov exponents and dynamical entropy.

In [103] we succeeded to find an appropriate definition for Lyapunov exponents for noncommutative algebras that provides the same consequences on the mixing behavior as in the classical case and does not depend on arbitrary choices.

For the dynamical theory for von Neumann algebras three definitions are now available (Connes-Størmer-Narnhofer-Thirring, Alicki-Fannes, Voiculescu). They had to be compared and it turned out that they react very differently on commutativity properties [104], [106], [129], [136]. Whether any of these dynamical entropies is related to Lyapunov exponents is at the moment not under control.

On the basis of C^* algebras a candidate for a topological dynamical entropy was proposed and examined in [93]. Also we examined the possibility to construct noncommutative systems with mixing dynamics. A natural possibility is to quantize classical Markov systems. But this quantization can be done in different ways. A comparison of these different possibilities with respect to the corresponding dynamical entropy should be finished in due time (seminar talk of Park, Benatti, Kümmerer, Narnhofer, Werner).

Another possibility to construct algebras with mixing automorphisms is based on the imbedding theory of algebras, where with a kind of mirroring process the imbedding can be enlarged to an automorphism group. This imbedding finds its counterpart in bipartite graphs. An essential step forward was done in [115] to single out those graphs that correspond to an imbedding.

Up to now we concentrated on an automorphism that can be extended to an automorphism group Z. Generalizations to other groups were treated in [86], [97], [108], [109].

An essential tool for explicit calculations of the entropy seems to be an appropriate characterization of the state space over the algebra. [102] concentrates on this problem. Further research by Petz and Michor and by Benatti, Narnhofer and Uhlmann is in progress.

Finally the theory of deterministic chaos was enlarged in [119] where the deterministic time evolution of quantum mechanics was combined with a probabilistic evolution representing quantum measurement in a consistent way.

Mathematical relativity

Organizers: P. Aichelburg and R. Beig

Total budget (including follow-up activities): ESI: ATS 850.000, external sources: ATS 100.000.

Dates: 1 July – 15 September 1994, including a Conference during the week 25 – 29 July 1994.

Preprints contributed: 18 (including [190], [266], [267], [206], [207], [251], [266]).

Report on the program

The field of Classical General Relativity (G.R.) has recently seen a significant upward swing, both in the quality and the number of published results. There seem to be three main reasons for the current renaissance of classical G.R.

One is the refined observations of effects where general relativity is essential, such as the Hulse-Taylor pulsar or the prospect of direct experimental detection of gravitational waves. The most notable effort in the latter direction is the LIGO project in the US, the construction of a system of earth-bound Laser Interferometric Detectors — at present the largest project funded by NSF. The correct interpretation of experimental results requires a solid understanding of the underlying theory.

A second factor is that G.R. is 'becoming of age' in the sense that the theory has reached a degree of maturity where many physically relevant questions can be given a rigorous mathematical formulation, typically at the geometry-analysis interface. There is moreover an increasing number of researchers with, not only a good command of the available mathematical machinery, but also the ability to further develop these techniques according to the requirements of the problems at hand.

A third element in the recent uprise of activity in Mathematical Relativity is that, with the power reached by current electronic computers, particularly when combined with insights coming from the analytical side, one can study problems which would have been considered out of reach a couple of years ago.

The Workshop on Mathematical Relativity, which ran from 1 July through 15 September, set itself the task of studying global existence and uniqueness questions for the Einstein Equations (EE's). The Einstein Equations with reasonable matter sources form a system of partial differential equations which give rise to a well-defined initial-value problem. In the initial-value formulation the EE's split into two sets: the constraint equations, an elliptic system which determines the set of allowable initial data, i.e. the phase space of G.R, and the hyperbolic system of evolution equations. The singularity theorems of Penrose and Hawking show that solutions with large data are necessarily singular in the sense of having incomplete causal geodesics. A major (perhaps 'the') open question in classical G.R, concerns the precise nature of the singularities developed by the maximal solution to the Cauchy problem, e.g, whether the maximal solution can be extended across a Cauchy horizon. That this should, for generic data, be impossible, is one version of the cosmic censorship conjecture. Another version states that, for many forms of matter, the maximal Cauchy evolution of asymptotically flat initial data will either approach flat spacetime or settle down to a stationary black hole state. For some matter sources one knows that these black hole states are characterized just by the gravitational mass, the angular momentum and the global charges of the matter sources ('no-hair property'). But recently Bartnik, McKinnon, Bizon and others have found non-abelian soliton-like and black hole solutions to the Einstein-Yang-Mills system which violate the above stated no-hair property. Since then such non-linear matter couplings to gravity have attracted much attention from physicists and mathematicians.The existence of regular non-abelian finite energy configurations in equilibrium with gravity results from a cancellation of gauge and gravitational singularities. This is a typical non-perturbative effect which shows that gravity can regularize divergences present in flat space theories. Another aspect is that the time development of perturbed soliton configurations may shed new light on the above mentioned cosmic censorship hypothesis. Furthermore, in the spherically symmetric case the static Einstein equations with non-linear field sources reduce to dynamical systems for which, it seems, modern methods of bifurcation and critical point theories may successfully be applied.

The work performed at the workshop concentrated on the following topics :

1. Gravity coupled to nonlinear matter sources (Aichelburg, Bartnik, Bizon, Chmaj, Choptuik, Forgacs, Gibbons, Maison, Smoller, Straumann, Wald.)

2. Black-Hole physics, No-Hair theorems (Chrusciel, Gibbons, Israel, Racz, Schmidt, Simon, Temple, Tod, Wald, Weinstein.)

3. Constraint Equations and Hamiltonian Reduction: Andersson, Bartnik, Beig, Fischer, Hajicek, Iriondo, Isenberg, Malec, Moncrief, O Murchadha.)

4. Evolution problems and Cosmic Censorship (Choptuik, Chrusciel, Friedrich, Hübner, Isenberg, Moncrief, Rein, Rendall.)

There were lively interactions between people working on these different topics and, whenever possible, with ESI visitors outside the Relativity program (examples: C.LeBrun, N.S.Nadirashvili). The workshop culminated in a **Conference on Mathematical Relativity** from 25-30 July, which was attended by roughly 100 people, many of whom were from former communist countries.

Program:
G. Gibbons: *Gravitating Solitons and Hairy Black Holes.*
R. Wald: *Classical Thermodynamics of Black Holes in Arbitrary Lagrangian Theories of Gravity Coupled to Matter.*
P. Chrusciel: *Strong Cosmic Censorship in Vacuum Spacetimes with Compact, Locally Homogeneous Cauchy Surfaces.*
N. O Murchadha: *Spherical Gravitational Collapse.*
Y. Choquet-Bruhat: *Non-Abelian Relativistic Fluids.*
M. Choptuik: *Critical Phenomena in Gravitational Collapse.*
P. Brady: *Self-Similar Scalar Field Collapse: Naked Singularities and Critical Behavior.*
A. Rendall: *Crushing Singularities in Spacetimes with Spherical or Plane Symmetry.*
G. Rein: *On the Spherically Symmetric Vlasov-Einstein System.*
R. Bartnik: *Solutions of the Einstein-Kaluza-Klein Equations.*
P. Bizon: *Gravitating Solitons and Hairy Black Holes.*
B. Temple: *An Astrophysical Shock-Wave Solution of the Einstein Equations Modeling an Explosion.*
H. Friedrich: *Boundary Conditions for Anti-de-Sitter Spacetimes.*
K. Newman: *The Structure of Conformal Singularities.*
W. Israel: *Effect on Radiative Wave Tails on Black Hole Interiors.*
D. Brill: *Testing Cosmic Censorship with Black Hole Collisions.*
H. Pfister: *Dirichlet Problem for the Stationary Einstein Equation with Applications to Stability Limits of Rotating Stars.*
N. Straumann: *On Einstein-Yang-Mills System for Arbitrary Gauge Groups.*
D. Maison: *Analytical and Numerical Methods for Einstein- Yang-Mills and Related systems.*
V. Moncrief: *Analytical and Numerical Studies of Spacetime Singularities.*
A. Fischer: *Classical and Conformal Superspace.*
M. Iriondo: *Existence and Regularity of CMC Hypersurfaces in Asymptotically Flat Spacetimes.*
G. Weinstein: *N-Black Hole Stationary Axially Symmetric Solutions of the Einstein-Maxwell System.*
B. Schmidt: *The Newtonian Limit of Einstein's Equations of Gravity.*

Quaternionic and hyper-Kähler manifolds

Organizers: D. Alekseevsky and S. Salamon

Total budget (including follow-up activities): ESI: ATS 450.000, external sources: ATS 30.000.

Dates: September to December 1994, including a Conference on Quaternionic and Hyper-Kähler Manifolds in Trieste during the week September 5–9, 1994, organized by St. Marchiafava, S. Salamon, M. Pontecorve, and D. Alekseevsky.

Preprints contributed: [135], [140], [148], [149], [158], [159], [172], [173], [186], [188], [191], [196], [197], [198], [205], [213], [219], [230], [247].

Report on the program

The main technical achievements are described below, and take into account (i) ESI preprints produced or in preparation, (ii) lectures given at ESI, and (iii) additional discussions or informal talks of relevant problems that are not covered by the preprint or lecture information. There is no doubt that the program was a great success in terms of the volume of work which it encouraged, and the on-going research advances that have been accomplished. The organizers wish to thank the Institute on behalf of all the participants.

Outline of work. The problems for investigation fell under the following headings.

1. Four-dimensional Riemannian and conformal geometry. A quaternionic structure on a real 4-manifold is the same as an oriented conformal structure, and a Riemannian 4-manifold has two compatible quaternionic structures. Quaternionic geometry may thus be viewed as an extension of the 4-dimensional theory.

   Preprints [156], [174], *Riemannian 4-manifolds with two Hermitian structures* by Kobak.

   Lectures (dates are in the form day/month): 4-dimensional integrable systems (V. Ogievetsky) 11/10; Conformally invariant Einstein geometry (Pedersen) 17/10; Twistor spaces of 4-manifolds (Pontecorvo) 9/12; Symmetry of self-dual manifolds (Poon) 9/12.

Additional discussions: Hermitian structures on 4-manifolds (Kobak, Nurowski, Pontecorvo, Salamon); T^2-actions on selfdual 4-manifolds (Pontecorvo, Poon); Einstein metrics on 4-manifolds (Cortes, Alekseevsky, Marchiafava); Moduli spaces of hyper-complex structures on 4-manifolds (Alekseevsky, Boyer, Nitta).

2. The geometry of quaternionic structures on higher-dimensional manifolds. This included studies of the various types of quaternionic manifolds and their associated twistor and other spaces. Work was done both on the construction of explicit classes of examples and on the general theory. Many classification issues remain open in eight and more dimensions, and this is likely to be a fruitful avenue for future research.

   Preprints [138], [142], [148], [150], [154] and *The Betti numbers of 3-Sasakian manifolds* (Galicki Salamon); Quaternionic transformations of non-positive quaternion-Kähler manifolds Alekseevsky, Marchiafava); Hyper-complex manifolds foliated by Hopf surfaces (Pedersen, Poon, Swann); Infinitesimal Einstein-Weyl deformations (Pedersen, Swann); The isometry group of the homogeneous quaternion-Kähler manifolds (Alekseevsky, Cortes).

   Lectures: On quaternion-Kähler manifolds, (LeBrun) 1/9; Weyl structures in quaternionic geometry (Piccinni) 16/9; Hyper-complex structures on solvable Lie groups (Dotti-Miatello) 28/9; Einstein metric and 3-Sasakian geometry (Galicki) 28/9; An explicit construction of hyper-Kähler metrics (Devchand) 12/10; Deformation of quaternionic structures (Nitta) 14/10; Hyper-Kähler manifolds associated to quaternion-Kähler manifolds (Swann) 17/10; Hyper-complex structures on Stiefel manifolds (Boyer) 19/10; Twistor construction for some Grassmann structures (Alekseevsky) 20/10; Decomposition of the exterior algebra of hyper-Kähler manifolds (Bonan) 23/11.

   Additional discussions: Invariant complex and hyper-complex structures on Lie groups (Dotti-Miatello, Salamon); torus actions on quaternion-Kähler manifolds, and divisors on twistor spaces and the classification of quaternionic structures (Battaglia, Pontecorvo, Poon).

3. Quaternion-Kähler and hyper-Kähler structures in physics. The latter has provided independent approaches of great value to determining examples and their classification.

   Preprints [134], [153], and *Gap phenomena for quaternionic Yang-Mills connections* (Taniguchi).

   Lectures: Complex and quaternionic geometries in supersymmetry and self-duality, informal talk and discussion, (V. Ogievetsky) 11/10; Gap phenomena for quaternionic Yang-Mills connections (Taniguchi) 20/10; Harmonic space description of quaternionic manifolds (Ivanov) 27/10; Instantons on quaternion-Kähler manifolds (Nagatomo) 7/11; Holonomy groups and extended supersymmetry in topological Yang-Mills theory (O. Ogievetsky) 14/11.

   Additional discussions: Geometrical meaning and formulation of harmonic space description of hyper-Kähler and quaternion-Kähler manifolds and its generalizations (Alekseevsky, Devchand, Ivanov, V. Ogievetsky); Dimensional reduction of supergravity and the relationship between special quaternionic-Kähler, special Kähler, and special Riemannian manifolds (informal talk by Van Proeyen); Lie group approach to the classification of homogeneous special Kähler manifolds (Alekseevsky, Cortes, Van Proeyen).

4. Other topics. This included work on areas not covered above but involving similar techniques.

   Preprints: *Homogeneous non compact Einstein 5-manifolds*, (Alekseevsky, Dotti-Miatello); *Invariant Poisson structures on semisimple Lie groups and symplectic structures on Borel subalgebras*, (Alekseevsky, Perelomov).

Lectures: Integrable systems of classical mechanics: integration of equations of motion (Perelomov) 18/10; Compact quotients of negatively curved manifolds with large isometry group (Podestà) 19/12.

Additional discussions: Kostant's generalization of the Borel-Weil theorem and its applications (informal talk by Nagatomo); Groups of automorphisms of CR structures (Alekseevsky and Spiro); Differential invariants of conformal and quaternionic structures (Alekseevsky, Slovak, Souček); Cohomology of cohomogeneity one compact manifolds (Alekseevsky, Losik); Relations between different diffeologies of some quotient spaces (Alekseevsky, Losik, Michor).

Participants:

Physicists: Ch. Devchand, E. Ivanov, O. Ogievetsky, V. Ogievetsky, A. Perelomov, A. Van Proeyen.

Mathematicians: D. Alekseevsky, F. Battaglia, E. Bonan, C. Boyer, V. Cortes, I. Dotti-Miatello, K. Galicki, G. Gentili, P. Kobak, C. LeBrun, S. Marchiafava, Y. Nagatomo, T. Nitta, H. Pedersen, P. Piccinni, F. Podestà, M. Pontecorvo, Y-S. Poon, S. Salamon, U. Semmelmann, A. Spiro, A. Swann, T. Taniguchi.

There were also a number of younger participants, including Battaglia, Cortes, Devchand, Kobak, Nagatomo, Semmelmann, Swann, Taniguchi.

Spinors, twistors and conformal invariants

Organizers: A. Trautman, V. Soucek, H. Urbantke (local organizer).

Total budget (including follow-up activities): ESI: ATS 500.000, no external funding.

Dates: September and October 1994.

Preprints contributed: [135], [140], [148], [149], [158], [159], [172], [173], [186], [192], [194], [201], [219], [227], [284].

Report on the program

Organization. The activity was a joint project on two topics: Spinor fields and Dirac operators; Twistors and conformal invariants. The activity took place in September and October 1994. The main concentration of participants was achieved around the conference 'Spinors, twistors and conformal invariants' organized at ESI during the week Sept 19 - Sept 23. The were 6 longer stays (2 stays for 8 weeks, 4 stays for 4 weeks) and 17 stays shorter than a month. The activity had a well balanced proportion of visitors coming from West and East.

There was another activity (Quaternionic and hyper-Kähler manifolds) organized at ESI during the same period, and there was a substantial interaction among participants of both activities. Lectures at the conference were attractive for participants of both activities, and the same was true for seminars of both activities as well. This made it possible to start a fruitful cooperation (e.g. on eigenvalues of Dirac operators on hyper-Kähler manifolds - A.Moroianu, U.Semmelmann; invariant operators on quaternionic and hypercomplex manifolds - D.Alekseevski, A.v Cap, J.Slovák, V.Souček).

The organization of the conference was quite smooth due to very efficient work by the administration; all practical problems concerning computer network were easily solved due to the very kind and efficient help of Andreas Čap. Sincere thanks are due to all of them.

The conference. There were 23 invited lectures and 8 shorter lectures. The main subjects discussed at the conference were the Penrose transform, conformal and CR invariants, Dirac operators and bounds on its lowest eigenvalues, twistor spaces and the twistor equation, deformations of twistor spaces, spinors and spinor fields in space-times, optical geometry, self-dual Yang-Mills fields and their relations to integrable systems.

The general impression felt from reactions of participants of the activity as well as from people coming to lectures was very positive. There were a lot of interesting lectures and several groups of people working in distinct but related fields (who usually do not meet) were brought together with a fruitful interaction coming as a result.

Main topics discussed during the activity. There were several different topics, some of them more mathematical, other ones more in mathematical physics. The topics were not always very close to each other, but there was a substantial interaction among participants working on different topics.

1. Invariants of conformal (more generally almost Hermitian symmetric) and CR structures: D. Alekseevski (quaternionic activity), T. Branson, J. Bureš, A. Čap, M. Eastwood, R. Graham, J. Slovák, V. Souček.

2. Optical geometry, CR-structures and the Kerr theorem, and related topics: R. Graham, J. Lewandowski, P. Nurowski, L. Mason, S. Salamon, A. Trautman, (P. Tod - by e-mail), H. Urbantke,
3. Dirac operators and spin structures on manifolds: A. Trautman, M. Cahen, S. Gutt, W. Kopczynski, J. Rawnsley.
4. twistor spaces, deformation theory: M. Eastwood, S. Huggett, L. Mason, S. Merkulov, J. Rawnsley,
5. The Penrose transform: T. Bailey, J. Bureš, M. Eastwood, L. Mason, V. Souček
6. Dirac operator and twistor operator on Riemannian manifolds and its spectral properties: H. Baum, T. Friedrich, O. Hijazi, A. Moroianu, U. Semmelmann (quaternionic activity).

Gibbsian random fields

Organizer: R. Dobrushin.

Total budget: ESI: ATS 400.000, no external funding.

Dates: August – December 1994.

Preprints contributed: [125], [176], [179], [183] (collection of abstracts).

Report on the program

The theory of Gibbsian fields is a quickly developing branch of science lying on the boundary between probability theory and statistical mechanics. The notion of Gibbsian random field having the origin in statistical mechanics turns out to be a very general way to describe random functions of many variables, and so found many applications in different sciences, including engineering, biology, and so on. Difficult mathematical problems arose in the study of properties of Gibbsian fields, especially in connection with the problem of phase transition.

The longer term visitors were R. Dobrushin, S. Shlosman, and O. Hryniv. Other scientists came only for the workshop.

Workshop: On the Ising model and around it in eight days, October 17–24, 1994.

Program:

A. van Enter, Groningen: *Ill-defined renormalization group maps: some new results,*
A. Messager, Marseille: *The Falicov-Kimball model is an Ising model,*
R. Dobrushin, Vienna - Moscow: *Estimates of semi-invariants for the Ising model at low temperatures.*
R. Kotecky, Praha: *The staggered charge order phase of the extended Hubbard model in the atomic limit,*
R. Schonmann, Los Angeles: *A study of the metastable behavior of the Ising model in the joint limit of small h and T,*
O. Hryniv, Vienna - Lviv: *Fluctuations of the 2D Ising model droplet around the Wulff shape,*
S. Shlosman, Vienna - Moscow - Irvine: *Restricted variational problem and the Ising model,*
Ch. Pfister, Lausanne: *Conditional Limit Theorems and Equivalence of Ensembles,*
M. Zahradnik, Praha: *Stratified Gibbs states of 3D Ising type models,*
E. Olivieri, Rome: *Ising model and renormalization group pathologies,*
Ch. Maes, Leuven: *Percolation techniques in disordered spin systems,*

Workshops organized outside the main programs

Winter school in geometry and physics

This traditional conference takes places each January since 1980 for one week in a picturesque village in the Czech parts of the Bohemian mountains is a joint enterprise of the Czech society of mathematicians and physicists and ESI, from 1994 onwards. ESI support was ATS 10.000. The first conference with ESI-participation was held during the period January 15–22, 1994. The proceedings of these meetings were published as a supplement of the 'Rendiconti Matematici di Palermo': Suppl. Rend. Circ. Mat. Palermo, II. Ser. **39** (1996), 9–148.

Contents:

International symposium in honor of Boltzmann's 150th birthday

This symposium was held during the week February 23–26, 1994, with ESI as a co–organizer, and was sponsored by a variety of organizations (AUA, BAWAG, CA, BMWF, etc.)

Apart from Schrödinger, Boltzmann is considered to be the most outstanding physicist of Austria whose thinking still influences mathematics and physics.

International scientists of the highest rank participated in the meeting, with the purpose to offer informative talks to international researchers as well as to the scientifically interested public of Vienna. The following preprints are from talks of this symposium: [81], [83], [85], [95], [98], [125].

List of lectures:

P. Schuster: *Die Prinzipien der biologischen Evolution und der Zweite Hauptsatz der Thermodynamik.*
W. Thirring: *Boltzmann's Legacy in the Thinking of Modern Physics.*
J. Lebowitz: *Time Arrow and Boltzmann's Entropy.*
T.D. Lee: *Vacuum as a Physical Medium (Relativistic Heavy Ion Collisions and the Boltzmann Equation).*
G. Gallavotti: *Ergodic Theory and Statistical Ensembles in Boltzmann's Work.*
G.G. Emch: *Concepts from Statistical Mechanics in Relativity.*
P. Schuster: *Statistics of Biopolymer Structures and the Boltzmann Distribution.*
O.E. Lanford III: *Microscopic Mechanics, Probability and the Boltzmann Equation.*
K. Schmidt: *Entropy for Mathematicians.*
D. Szász: *Boltzmann's Ergodic Hypothesis, a Conjecture for Centuries?*
W. Stiller: *Ludwig Boltzmann und die Entwicklung der chemischen Kinetik.*
H.A. Posch: *Numerische Simulation von Vielteilchensystemen im Gleichgewicht und Nichtgleichgewicht.*
E. Oeser: *Boltzmann und die evolutionäre Erkenntnistheorie.*
D. Flamm: *Leben und Werk Ludwig Boltzmanns.*
R. Dobrushin: *A Mathematical Approach to Foundations of Statistical Mechanics.*
G. Fasol: *The Boltzmann Equation and Its Limits in Solid State Physics.*
A. Uhlmann: *Comparison of Probability Distributions.*

The year 1995

General remarks

Management of the Institute

President: Walter Thirring
Director: Klaus Schmidt
Deputy Director: Peter Michor
Administration: Mario Springnagel, Elisabeth Haffner, Lilla Hartyani
Computers: Andreas Čap, Hermann Schichl

International Scientific Advisory Committee

P. Budinich (Trieste)
A. Connes (IHES)
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A.M. Vinogradov (Moscow)
J. Wess (Munich)
W. Reiter (Bundesministerium für Wissenschaft und Forschung)

Budget and visitors: The budget of ESI for 1995 was ATS 10,6 Mio. (about €770.300). ATS 4,7 Mio. were spent on scientific activities and ATS 5.4 Mio. on administration, infrastructure, and adaptation of the building. Visitors supported from other sources contributed the equivalent of a further ATS 1,38 Mio.

The number of scientists visiting the Erwin Schrödinger Institute in 1995 was 217, and the number of preprints produced was 108.

Programs in 1995

Complex analysis

Organizer: F. Haslinger.

Total budget (including follow-up activities): ESI: ATS 270.000, no external funding.

Dates: January – March 1995.

Preprints contributed: [195], [199], [203], [215], [216], [232], [253].

Report on the program

The main topics were CR-manifolds and functions, geometric aspects of complex analysis, application of functional analysis to complex analysis and partial differential equations, $\overline{\partial}-$ equations, Bergman and Szegö kernels.

Some colleagues stayed for a longer period at the ESI (Daryl Geller, Takeo Ohsawa, Peter Greiner, John Wermer, David Tartakoff) most of the participants concentrated their visit around the week Feb. 20 - Feb. 24, where a workshop took place with 20 45-minute lectures.

Program:

B. Berndtsson: Some problems connected with interpolation and sampling of analytic functions.
J. Bros: Transformations of Fourier-Laplace type and related holomorphy domains on the complex hyperboloid.
R. Dwilewicz: Type functions for CR manifolds.
Ch. Epstein: A relative index for CR-structures.
Laura Geatti: Complex symmetric spaces.
D. Geller: Partial differential equations on the Heisenberg group.
P. C. Greiner: Hamiltonian mechanics and fundamental solutions for subelliptic operators.
A. Iordan: Compactness of the Neumann operator for piece-wise smoothly bounded strictly pseudoconvex domains.
M. Langenbruch: Splitting of the $\overline{\partial}$-complex.
L. Lempert: Algebraic approximations in analytic geometry.
J. McNeal: The Bergman and Szegö projections on convex domains.
R. Meise: Extension and lacunas of solutions of linear partial differential equations.
S. Momm: Partial differential equations for analytic functions on compact convex sets in $mathbf{C}^N$.
P. Müller: The Banachspace $H^1(X, d, \mu)$ (isomorphic classification).
T. Ohsawa: On the variation of the density and an application to interpolation problems.
H.S. Shapiro: Partial differential equations and analytic continuation.
R. Szöke: Hypercomplex structures on the tangent bundles of hermitian symmetric spaces.
D. Tartakoff: The smoothness of solutions to the $\overline{\partial}$-equation and applications.
H. Upmeier: Toeplitz operators and geometric quantization in several complex variables.
V. Vâjâitu: On Levi q-convexity.
D. Vogt: Solution operators for linear partial differential operators of second order and fundamental solutions with support in a half space.
J. Wermer, USA: Interpolation bodies in $\mathbf{C}^n$.

Noncommutative differential geometry

Organizers: A. Connes, M. Dubois-Violette and P. Michor.

Total budget (including follow-up activities): ESI: ATS 500.000, external sources: ATS 70.000.

Dates: May 1995.

Preprints contributed: [210], [228], [235], [269], [285], [290], [296], [299].

Report on the program by P. Michor

Central part of this program was a **Conference** in the Czech Republic, in the castle of Třešt, May 8 – 13, which was organized by the Union of Czech Mathematicians and Physicists, the Erwin Schrödinger Institute of Mathematical Physics in Vienna (with a contribution of ATS 10.000), together with the Institute of Mathematics and Institute of Physics of Czech Academy of Sciences and the Faculty of Mathematics and Physics of Charles University. The most exciting event at the conference was a new noncommutative representation of the standard model by A. Connes, which restricts some of the free parameters more tightly than the old one. The program of this conference was as follows:

PLENARY LECTURES:

Chamseddine A.: Unification, gravity and supersymmetry in NG.
Connes A.: Geometry from the spectral point of view.
Coquereaux R.: Fractal triangular dissections, Jones algebras and NG.
Doplicher S.: The small scale structure of spacetime, gravitational stability and quantum field theory.
Dubois-Violette M.: Connections on certain classes of bimodules and reality conditions in NG.
Gawedzki K.: Conformal field theory and NG.

Karoubi M.: Algebres graduees mixtes.
Kastler D.: Constraints of the standard model a la Connes-Lott.
Kerner R.: Z-3 graded differential calculus and new gauge theories.
Klimcik C.: NG and supersymmetry.
Madore J.: Linear connections in NG.
Michor P.: Derivation based constructions on central bimodules.
Rieffel M.: Deformation quantization.
Roberts J.: Physical and mathematical aspects of spacetime.
Todorov I.: Non-commutative configuration space in WZNW model.
Connes A.: Geometry from the spectral point of view, II.

AFTERNOON LECTURES:

Bona Pavel: On Lie-Poisson structure on quantum states.
Borowiec Andrzej: Constructive approach to non-commutative differential calculi.
Brodzki Jacek: Supertraces and entire cyclic cohomology.
Brzezinski Tomasz: Geometric aspects of the quantum group gauge theory.
Cap Andreas: On twisted tensor products of algebras.
Ferretti Gabriele: Schwinger terms and cohomology of pseudodifferential operators.
Friedlander Leonid: L^2 - analytic torsion and L^2 - Reidemeister torsion.
Gracia-Bondia J.M.: Connes' interpretation of the standard model and massive neutrinos.
Iochum Bruno: Yang-Mills-Higgs versus Connes-Lott.
Kalau Wolfgang: Supersymmetric Connes-Lott models.
Kaviani Kamran: Chiral perturbation theory in the framework of NG.
Kopf Tomas: The evolution of spacetime encode into a scalar field algebra.
Lee Chang-Yeong: BRST and anti-BRST symmetry in noncommutative geometric gauge theory: matrix derivative approach.
Martin C. P.: Quantum corrections and the stability of the ngc constraints on the parameters of the standard model.
Presnajder Peter: Finite gauge model in non-commutative geometry.
Schucker Thomas: Yang-Mills-Higgs versus Connes-Lott.
Sitarz Andrzej: Problems with metric and linear connections in NG.

POSTERS:

Drabant Bernhard: Quasitriangular structures in braided tensor categories.
Le Roy Bertrand: Hypermatrices: a Z-3 graded matrix algebra.
Lizzi Fedele: Noncommutative Lattices as Finite Approximation of Topological Spaces.
Post Gerhard: Differential calculus on Universal Enveloping Algebras.

Field theory and differential geometry

Organizers: G. Marmo and P. Michor.

Total budget (including follow-up activities): ESI: ATS 897.000, external sources: ATS 368.000.

Dates: May 15 – July 31, 1995.

Preprints contributed: [200], [218], [224], [229], [231], [236], [239], [240], [241], [242], [243], [245], [246], [247], [248], [254], [255], [256], [261], [277], [279], [282], [289], [293], [299].

Report on the program by P. Michor

The program concentrated on following themes (listed with the participants working in this area):

1. Differential geometry and its applications: Asorey, Ibort, Grabowski, Marmo, Michor, Perelomov, Simoni, Tulczyjew, Vilasi.

2. Spectral Geometry and Torsion: Burghelea, Friedlander. Their theory was the subject of an interesting series of lectures.

3. Infinite dimensional Lie algebras and Lie groups: Borodin, Grabowski, Kirillov, Michor, Mickelsson, Rozhkovskaya. Here a very interesting series of lectures by A. Kirillov on *Infinite dimensional Lie algebras and their representations* is to be mentioned.

4. Gauge theories and current algebras: Langmann, Mickelsson, Rajeev, Stern, Vitale.

5. Finite approximations to quantum physics: Balachandrian, Bimonte, Landi, Lizzi, Sparano, Teotonio-Sobrinho.

Gibbs random fields and phase transitions

Organizers: R. Dobrushin and R. Kotecký.

Total budget (including follow-up activities): ESI: ATS 982.000, no external funding.

Dates: October – December 1995.

Preprints contributed: [281], [283].

Report on the program by R. Kotecký

The semester was overshadowed by the sad news of Roland L. Dobrushin's death (on 12th November 1995 in Moscow), who was the main organizer. Even though his deteriorating health did not allow him to come, many discussions were influenced by his recent ideas.

The following colleagues participated in the program of the semester in Vienna: Marek Biskup (1 week), Anton Bovier (2 weeks), Lincoln Chayes (8 weeks), Filippo Cesi (2 weeks), Efim Dinanburg (6 weeks), Roberto Fernandez (2 weeks), Roman Kotecký (10 weeks), Christian Maes (4 weeks), Vadim Malyshev (2 weeks), Fabio Martinelli (3 weeks), Igor Melicherčík (1 week), Boris Nakhapetjan (8 weeks), Enzo Olivieri (3 weeks), Senya Shlosman (1 week), Daniel Ueltschi (2 weeks), Miloš Zahradník (8 weeks).

The program started with a workshop in Churáňov (Czech Republic) attended by: M. Biskup, C. Borgs, A. Bovier, L. Chayes, J.-D. Deuschel, E. Dinanburg, R. Fernández, F. Hollander, P. Holický, O. Hryniv, D. Ioffe, M. Janžura, P. Kotalík, R. Kotecký, P. Marchetti, A. Martin-Löf, J. Mięykisz, S. Miracle-Solé, B. Nakhapetian, C. Pfister, J. Ruiz, F. Slanina, D. Ueltschi, A. van Enter, M. Winnink, M. Zahradník.

Among the topics discussed were:

1. Dobrushin's program for defining relative energies for weakly non-Gibbsian measures (C. Maes, L. Chayes, R. Kotecký, E. Olivieri, M. Zahradník): A proposal made by R. Dobrushin at a workshop in Renkum (in September) was discussed. Certain pathologies in transformations of Gibbs measures for some models can be treated analogously to the so called Griffiths' singularities in disordered systems.

2. The Kac Model (A. Bovier, M. Zahradník): The low temperature phase of the d-dimensional Kac Model was discussed. The aim was to prove that the critical temperature T_c is greater than or equal to $1 - \gamma^x$ for some $x > 0$, where γ is the inverse of the range of the interaction. The validity of the Peierls argument was investigated for these models.

3. The Ising model with alternating field (E. Olivieri, L. Chayes, M. Zahradník): The problem of its low temperature phase diagram was almost solved. In general we are dealing with the structure of low temperature phases of two dimensional models whose contours do not satisfy the ordinary Peierls condition but a weaker property: the energy of such contours is the sum of the 'corner energy' which has a high density and the 'segment energy' having a small density. The possibility of extending the Pirogov-Sinai theory to these cases was established.

4. The spin flip dynamics of disordered systems ((F. Cesi, C. Maes, F. Martinelli, M. Zahradník): We started working on the glassy dynamics for randomly diluted magnets. Both upper and lower bounds for the relaxation of the disordered system to equilibrium were derived.

5. Diluted models with continuum spins (L. Chayes, R. Kotecký, S. Shlosman): We discussed the existence of 'entropic' intermediate phases for lattice models with continuous spin and annealed dilution.

6. Intermediate phase for a continuum model (L. Chayes, R. Kotecký): A continuum four component model of Widom-Rowlinson type with an Ashkin-Teller symmetry was discussed. This model has two phase transitions with four distinct phases at high fugacity and two distinct phases in an intermediate fugacity regime.

7. A Potts model with transition between two disordered states (M. Biskup, L. Chayes, R. Kotecký): We investigated a possibility to use reflection possibility for a class of random cluster models and an application to a particular class of Potts models.

8. Pirogov-Sinai theory for quantum models (R. Fernández, R. Kotecký, D. Ueltschi, E. Dinanburg): Different aspects of this problem were discussed including fermi and bose systems as well as corresponding degenerate models.

9. Dynamics of non Hopfield neural networks (V. Malyshev): General methods which were developed earlier for telecommunication networks were applied to neural networks introduced by M.Cottrell. Strong properties of the dynamics were proved: convergence to the patterns starting from noisy patterns.

10. Lifshitz law for the life-time of a droplet in the low temperature Ising model (L.Chayes, F. Martinelli).

11. Asymptotic behaviour for 1D symmetric exclusion with moving boundaries (O. Hryniv, L. Chayes).

12. Invariant measures for 1D asymmetric exclusion process (O. Hryniv, V. Malyshev).

13. Mixing properties and limit theorems for random fields (O. Hryniv, B. Nahapetian).

14. The question of the completeness of the phase picture constructed by the P.S. theory (M. Zahradník, I. Melicherčík).

15. Generalized Gibbs distributions (V. Malyshev, B.Nahapetian).

16. Dynamics for Hopfield networks with Small Number of Patterns (V. Malyshev, L. Pastur, M. Scherbina).

Reaction-diffusion equations in biological context

Organizers: K. Sigmund, R. Bürger and J. Hofbauer.

Total budget: ESI: ATS 207.000, no external contributions.

Dates: September 1 – November 15, 1995.

Report on the program by K. Sigmund

The participants were P. Brunovsky, K. Mischaikov, T. Nagylaki and V. Hutson.

Reaction-diffusion equation have been studied (in the context of population genetics) since 1937, but only recently has one studied the effect of different diffusion rates (biological motivation: diffusion rates are evolutionary variables, and subject to selection). The central question discussed during the workshop was: if different diffusion rates carry no selective advantage per se (i.e. all have the same fitness), will there still be selection for some particular rate? We assume, for instance, a one-dimensional distribution of the population along an axis, and a carrying capacity which is not constant and can even be negative in some spots. Under the assumption of asexual replication, and only two different diffusion rates, it turned out that there was always selection for the smaller one. This could be proved analytically, using the theory of monton flows, even in the case of adding small mutation rates to the equation. For more than two rates, the result is probably true, but its proof has still a gap (even for the no mutation case). Considerable effort has been made to develop more sophisticated models including sexual replication, recombination, and drift. Among the problems still at an exploratory stage, we mention: what happens if there is a cost attached to diffusion rates that are too small, or too large? Is there a selective advantage for higher diffusion rates if the carrying capacity oscillates periodically?

Another center of gravity for the discussions was the theory of travelling waves for frequency-dependent selection. This can be studied using evolutionary games (more precisely, reaction-diffusion variants of the replicator equation). The bistable situation was of particular interest. It was shown that

under certain circumstances bistable waves exist (with a change of sign for the velocity of the density of one of the two competing types). This was applied to the study of the iterated Prisoner's Dilemma, with special emphasis on the invasability of a population of defectors by strict retaliators.

Condensed matter physics: dynamics, geometry, and spectral theory

Organizers: V. Bach and R. Seiler.

Total budget (including follow-up activities): ESI: ATS 1,78 Mio., external sources: ATS 182.000.

Dates: August 6, 1995 – February 24, 1996.

Preprints contributed: [259], [264], [270], [271], [272], [275], [276], [280], [291], [294], [295], [297], [302], [306], [308], [313], [330], [331], [339], [352], [380], [383].

Report on the program

The main objective of this program was to bring scientists together from active areas of mathematics and physics, ranging from applied mathematics and mathematical physics to theoretical condensed matter physics, and to give them the opportunity to talk to each other - people who probably would not have met otherwise.

Throughout the program, as many young postdoctoral scientists were present as established senior scientists. Altogether, more than a hundred physicists and mathematicians participated in the program. Notably many long-term visitors were among them, the average staying length amounted to twenty days, approximately.

Scientifically, the program was centered around five workshops that were held during the program:

- Workshop on *Transport Phenomena and Chaos,* August 13 – 26, 1995;
- Workshop on the *Hubbard and Heisenberg Model,* August 27 – September 9, 1995;
- Workshop on *Singular Spectra,* October 23 – 28, 1995; a collection of the abstracts of the seminars is available as ESI-Preprint [280].
- Workshop on *Field Theoretic Methods for Fermion Systems,* January 21 – February 3, 1996;
- Workshop on *Condensed Matter Physics and Discrete Geometry,* January 21 – February 3, 1996;

Workshops organized outside the main programs

Winter school in geometry and physics

January 14–21 1995, Srní, Czech Republic, with a contribution of ATS 10.000 from ESI. The proceedings were published in Suppl. Rend. Circ. Mat. Palermo, II. Ser. **43** (1996), 9–228

Contents:

Geometry of nonlinear partial differential equations

This small meeting was organized by A. Vinogradov and J. Krasil'shchik and was funded by ESI with ATS 93.000. The resulting preprints were [202], [257], [260].

Semi-classical limits and kinetic equations

This two-day workshop was organized by C. Schmeiser during the days November 27 - November 28, 1995. The following talks were presented:

W. Thirring: Derivation of the Thomas-Fermi theory from the Schrödinger Equation,
T. Paul: Semiclassical methods using coherent states,
H. Narnhofer: Vlasov hydrodynamics for a quantum mechanical model,
A. Arnold: The relaxation-time von Neumann-Poisson equation: existence, uniqueness, large time behaviour,
B. Perthame: Time Decay in Kinetic Equations, Relations with Schrödinger and Fluid Cases,
M. Pulvirenti: On the Enskog equation: Derivability from particle systems,
I. Gasser: The classical limit of Hartree-Fock systems,
N. Mauser: Wigner transforms and homogenization limits,
R. Illner: Global weak solutions of the Boltzmann equation in a slab with stochastic boundary conditions,
F. Poupard: Semiclassical limits and effective mass theorems,
P. Gérard: Wigner measures and Concentration Effects
A. Unterreiter (Berlin): The stationary quantum drift-diffusion model,
C. Ringhofer: Approximate equilibria of quantum mechanical systems and applications to quantum kinetic and quantum hydrodynamic models,
P. Degond: Macroscopic models for semi conductors,
A. Zwirchmayr: Convergence of moment expansions for the semiconductor Boltzmann equation.

Visitors outside the main programs

Visitors to ESI not associated with any of the main programs and workshops contributed the preprints [187], [199], [209], [220], [221], [222], [223], [226], [265], [267], [286], [287], [288], [292], [268], [273], [300], [301], [252], [278].

The year 1996

General remarks

Management of the Institute

President: Walter Thirring
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Vaughan Jones (Berkeley)
Alexander Kirillov (Pennsylvania)
Othmar Loos (Innsbruck)
Domokos Szasz (Budapest)
Jakob Yngvason (Vienna)

Budget and visitors: The budget of ESI for 1996 was ATS 11,1 Mio. (€ 806.700). ATS 4,426 Mio. were spent on scientific activities and ATS 6,6 Mio. on administration, infrastructure and adaptation of the new premises (see below). Visitors supported from other sources contributed the equivalent of a further ATS 1,2 Mio.

The number of scientists visiting the Erwin Schrödinger Institute in 1996 was 259, and the number of preprints produced was 120.

At the end of July 1996 ESI moved into its new premises on the second floor of the building in Boltzmanngasse 9, 1090 Wien. The building is over 200 years old and was built as an orphanage during the rule of the emperor Joseph II.

Programs in 1996

Topological, conformal and integrable field theory

Organizers: K. Gawedzki and H. Grosse.

Total budget (including follow-up activities): ESI: ATS 794.000, external sources: ATS 8.000.

Dates: February 15 – May 14, 1996.

Preprints contributed: [315], [316], [317], [318], [319], [320], [321], [322], [323], [327], [335], [336], [350], [362], [370], [371], [378], [386], [389], [391], [407]. .

Report on the program

The aim of the activity was to bring together a number of specialists in the three interrelated domains in order to stimulate the research on their front lines. A special emphasis was put on the development of methods applicable in more than one of the three fields.

Special thanks are due to the permanent stuff of the Institute which assured much needed flexibility in organization of the activity and more than smooth handling of all practical problems.

An important part of the program dealt with conformal field theories. These are theories describing critical phenomena in 2-dimensional statistical-mechanical systems and vacua of string theory. One of the main open problems of conformal field theory is that of classification of the rational models. The research in this direction was conducted by Ganchev, Ganon, Petkova Schroer and Stanev. Ganon has pursued the work on the classification of modular invariant partition functions of theories with Kac-Moody symmetries by methods based on the Galois symmetries inherent in the action of the modular group whereas the Bulgarian group studied the fusion algebras related to rational level Kac-Moody algebras and constructed correlation functions out of the corresponding solutions of the Knizhnik-Zamolodchikov equations (in the joint preprint with Furlan). Schroer pursed his approach to the classification based on algebraic field theory methods. It has become more and more evident that the three methods, based on the study of monodromies of correlators, are closely related and involve interesting number theory aspects of quantum fields deserving further investigation.

The applications of conformal field theories to quantum Hall effect were studied by Cappelli and by Todorov (in a joint preprint of the latter with V. Kac). The idea is to search for new families of conformal models with W-algebra symmetries which may describe the Hall boundary currents. Not too surprisingly, it appeared that this program is strongly related to the classification problem of rational models of conformal field theory. The work conducted at ESI has permitted to put forward a new list of conformal models for Hall fluids.

The analysis of differential equations satisfied by the conformal field correlators has been one of the principal tools of conformal field theory. Alekseev-Recknagel-Schomerus in a joint work have shown how to obtain and analyze equations generalizing the Knizhnik-Zamolodchikov ones for a large class of conformal field theories. This work opens a possibility to directly apply the methods used in the analysis of WZW models to other models of conformal field theory.

The appearance of structures typical for integrable models in conformal field theories has been a subject of an intense study. One of such relations is that between the integral formulae for the conformal blocs (solutions of the KZ equations) and the Bethe Ansatz for spin chains. The topic which, as indicated by recent works of Beilinson, Drinfeld, Feigin and Frenkel exposed by the latter in a series of seminars at ESI, is related to the geometric Langlands program. It has been analyzed in the case of genus 1 in the joint work of Falceto and Gawedzki where the Bethe-Ansatz formulae for general group where obtained by exact calculation of field theory functional integrals and were shown to encode hermitian structures on the bundles of non-abelian theta functions.

The connections of the Knizhnik-Zamolodchikov equations and integrable models were also studied by Felder, Varchenko and Veselov. On one hand side the KZ equations may be considered as a quantization of the Hitchin integrable system and in the genus one case they lead to a quantum elliptic Calogero-Moser system or its spin versions. On the other hand, the deformation of the equations to a finite difference ones, gives rise to new integrable models based on elliptic quantum groups whose intricate representation theory has been studied by Felder and Varchenko.

Another application of conformal field theory techniques to integrable systems was developed by Bonora who has generalized the Drinfeld-Sokolov construction of integrable hierarchies to the N=2 supersymmetric case and by Olshanetsky who has obtained a novel description of Hitchin systems.

One of the main directions in the theory of integrable two-dimensional field theories has been the work on exact formulae for form-factors, started by Smirnov. Musardo exposed the application of this methods to a series of deformations of minimal conformal theories. Al. Zamolodchikov analyzed its relation with the thermodynamical Bethe Ansatz. Bernard and Babelon (in a joint paper with Smirnov, completed at ESI) have found an interpretation of the form-factor formulae as a semiclassical description of the soliton scattering. A fundamental role in their work has been played by a new quantum deformation of Riemann surfaces which deserves further studies.

The inclusion of the ideas of non-commutative geometry into field theory has been a subject of work of Grosse Klimcik and Presnajder who, in a series of ESI preprints, developed quantum field theories on non-commutative spaces and constructed theories with two-dimensional fermions (using supersymmetry), with non-trivial topological sectors and first four-dimensional models. Their constructions provide a new type of cutoffs for field theory which preserve the essential symmetries, but may also play a more fundamental role. In another attempt to marry non-commutative geometry with field theory, Alekseev Faddeev and Schomerus (with Fröhlich) made progress in the study of lattice 1+1 dimensional models with fields taking values in quantum groups. Such models possessing lattice versions of Kac-Moody and conformal symmetries may be constructed from representation theory of discretized Kac-Moody algebras developed by the authors.

The conformal field theory ideas (more concretely, the geometric analysis of WZW models) found also an application in the work of Assorey and Falceto who analyzed the vacuum nodes of the ground state of three-dimensional gauge theory, confirming Feynman's conjecture that the node structure is related to the confinement mechanism. An attempt to extend the geometric construction of the WZW model of conformal field theory to four dimensions was described in a series of brilliant seminars by Nekrasov, summarizing his work with Losev, Moore and Shatashvili and its relation to the recent developments in supersymmetric Yang-Mills theory and to the Seiberg-Witten invariants. The recent duality ideas in gauge field theories were discussed in talks by Olive (a general exposition) and by Schwimmer (on his work on the generalizations to higher rank groups). The mysterious occurrence of integrable models in the low energy effective actions of supersymmetric gauge theories was studied by Morozow and by Dubrovin who developed a unified approach to low energy prepotentials based on the Witham hierarchies. The relation between the Seiberg-Witten and Donaldson invariants was the subject of the research of Stora who exploited the relations between the topological field theories and the equivariant and BRST cohomologies.

Finally, although the string theory and quantum gravity did not belong to the main subjects of the program, their relations with conformal and topological field theories were the topics of research by Pawelczyk (who found new topological instanton configurations for a model of rigid string), of Schimmrigk and Theisen (mirror symmetry of string vacua) and of Durhuus and Jonson who pursued their analysis of phase transitions in discrete models of random surfaces.

Representation theory with applications to mathematical physics

Organizers: I. Penkov, J.A. Wolf and P. Michor (local organizer).

Total budget (including follow-up activities): ESI: ATS 1.246.800, external sources: ATS 331.000.

Dates: April - June, 1996.

Preprints contributed: [324], [325], [328], [332], [333], [334], [338], [340], [341], [342], [344], [345], [348], [349], [353], [354], [357], [361], [375], [376], [381], [398], [404], [407], [488], [492].

Report on the program

The main idea of the program was to present today's Representation Theory in all its diversity. Another idea was to foster active interaction between three major schools in Representation Theory: the American, the Western European, and the Russian. Along with the about 35 senior participants, the program hosted about 20 graduate students of US Universities sponsored jointly by ESI and the NSF (via a special NSF grant of USD 24000). Another feature was the considerable interaction with the Mathematical Physics program organized by K. Gawedski.

The following areas of representation theory were best represented in the program:

- Representations of real Lie groups: analytic and geometric methods;
- Structure theory of Lie algebra representations;
- Structure theory of quantum groups;

- Lie superalgebras, Lie supergroups, and their representations;
- Invariant theory;
- (Co)homology of Lie algebras and applications;
- Infinite-dimensional Lie groups and differential operators;
- Applications of Representation Theory to Mathematical Physics and to Geometry.

Here is a list of talks presented in the program:

D. Alekseevsky, Sophus Lie Centre, Moscow, Classification of n-extended Poincare Lie algebras and Lie superalgebras.
A. Astashkevich, UC Davis, On the Fedosov quantization of semisimple coadjoint orbits.
L. Barchini, Temple University, Unitary representations and harmonic forms (with Roger Zierau).
M. Eastwood, University of Adelaide, Zero energy fields on real projective space.
A. Fialowski, UC Davis, Deformations of the vector field Lie algebra L1.
M. Flatto, University of Bourgogne, Deformation quantization: deforming Nambu mechanics.
I. Frenkel, Yale University, Four-dimensional realizations of two-dimensional current groups.
D. Fuchs, UC Davis, Massey products.
V. Futorny, University of Kiev, Alpha-stratified weight modules for finite-dimensional Lie algebras.
V. Futorny, University of Kiev, Representations of affine Lie algebras.
S. Gindikin, Rutgers University, $\bar{\partial}$-cohomology at nonconvex tubes.
M. Golinshcheva-Kutuzova, Inst. of Nonlin. Sciences, Intertwining operators and integrable hierarchies of soliton equations.
V. Kac, MIT, Quantum orbifolds.
A.A. Kirillov, Jr., MIT, Cohomology of local systems and canonical basis.
A.A. Kirillov, Sr., University of Pennsylvania, Tame algebras of differential operators.
B. Kostant, MIT, Quantum cohomology of the flag manifold, the Toda lattice and the representation of highest weight ρ.
G. Litvinov, Institute of New Technologies, Moscow, Lie hypergroups and their representations.
G. Litvinov, Institute of New Technologies, Moscow, Non-unitary representations of the Heisenberg group.
G. Lusztig, MIT, Asymptotic properties of Hecke algebras and quantum groups.
F. Malikov, USC, Singular support of g-modules and an attempt to build GFT using admissible representations.
O. Mathieu, University of Strasbourg, Canonical operations in symplectic geometry.
O. Mathieu, University of Strasbourg, Obstructions for Hodge theory on symplectic manifolds.
P. Michor, ESI, Basic differential forms for actions of Lie groups.
P. Michor, ESI, Choosing roots of polynomials smoothly alias lifting of curves over invariants.
D. Milicic, University of Utah, On the classification of irreducible Harish-Chandra Modules.
M. Nazarov, University of Swansea, Yangians and Capelli identities.
Y. Neretin, Moscow Inst. of Electronics and Math., Boundary values of holomorphic functions and singular unitary representations of groups O(p,q).
J. Novak, Ball State University, USA, Explicit realizations of certain representations of Sp(n,R) via the Penrose transform.
A. Onishchik, Yaroslavl University, Supermanifolds associated with Symmetric spaces.
I. Penkov, UC Riverside, Representations of arbitrary finite-dimensional Lie superalgebras.
V. Popov, Moscow State Technical University, An analogue of M. Artin's conjecture on invariants for non-associative algebras.
V. Protsak, Yale University, On a geometric approach to vertex operator algebras.
M. Rosso, University of Strasbourg, Quantum groups and quantum shuffles.
A. Rudakov, Russian Academy of Sciences, Representation-like properties of vector bundles.
V. Serganova, UC Berkeley, Representations of the Lie superalgebra q(n).
J. Simon, University of Bourgogne, Global solutions of the Maxwell-Dirac equations.
E. Sommers, MIT, A family of representations of a Weyl group, and applications.
E. Stern, UC Berkeley and University of Pennsylvania, Semi-infinite wedges and combinatorics.
D. Sternheimer, CNRS, France, Recent developments in deformation quantization and quantum groups.
T. Takebe, UC Berkeley and University of Tokyo, A system of difference equations with elliptic coefficients and Bethe vectors.
A. Vershik, Russian Academy of Sciences, St. Petersburg, Inductive construction of Coxeter group representations.
E. Vinberg, Moscow State University, On invariants of a set of matrices.
J.A. Wolf, UC Berkeley, Linear cycle spaces and double fibration transforms.
S. Woronowicz, University of Warsaw, Remarks on quantum SU(1,1).
D. Zhelobenko, Independent University, Moscow, Hypersymmetries on extremal equations.
R. Zierau, Oklahoma State University, Unitary representations and harmonic forms (with Leticia Barchini).
G.J. Zuckerman, Yale University, Lie superalgebras in Poisson and complex geometry.

Mathematical problems of quantum gravity

Organizers: A. Ashtekar and P.C. Aichelburg.

Total budget (including follow-up activities): ESI: ATS 770.000, external sources: ATS 13.000.

Dates: July – August, 1996.

Preprints contributed: [307], [327], [351], [363], [364], [365], [366], [367], [368], [369], [373], [379], [390], [392], [393], [394], [397], [417], [418], [420], [422], [430], [441], [456], [457], [458], [459], [462], [463], [472], [473], [474], [476], [509], [510], [517]. .

Report on the program

There were 23 participants from outside Austria, mostly young physicists who have been working on various aspects of quantum gravity. In addition, about a dozen faculty and students from Vienna actively participated in the seminars and discussions. While the focus of this effort was on non-perturbative quantum general relativity, there were several experts from string theory, supergravity, quantum cosmology, quantum field theory, as well as mathematical physics in a broad sense of the term. There were two weekly seminars which were widely announced – one entitled 'fundamental issues', and the other, 'advanced topics'. They enhanced the scientific interaction between workshop participants and the local physics and mathematics community. In addition, there were discussion seminars three days a week. The afternoons were left open for further informal discussions (and real work!). On the scientific front, the workshop elevated the subject to a new level of maturity. It enabled the participants to take stock of a number of areas to obtain a global picture of issues that are now well-understood and also opened new directions for several other key issues. The following main topics were discussed during the workshop (the names in parentheses refer to participants who contributed to the specific topic):

- *Quantum Hamiltonian constraint.* (Hans-Jürgen Matschull, Jorge Pullin, Carlo Rovelli, Thomas Thiemann)
- *Quantum geometry.* (A. Ashtekar, J. Lewandowksi, R. Loll, T. Thiemann)
- *Lattice methods and skeletonization in loop quantum gravity.* (R. Loll, M. Reisenberger)
- *Super-selection rules in quantum gravity.* (A. Ashtekar, J. Lewandowski, D. Marolf, J. Mourao, T. Thiemann)
- *Degenerate metrics: extensions of GR.* (T. Jacobson, J. Lewandowski, H.-J. Matschull)
- *Global issues, Hamiltonian formulations.* (F. Barbero, D. Giuilini)
- *Mathematical issues in quantum field theory and quantum gravity.* (J. Baez, M. Blau, H. Balasin, R. Gambini, J. Mourao, D. Marolf)
- *Exactly soluble midisuperspaces.* (A. Ashtekar, H. Nicolai)
- *Lessons from low dimensional gravity.* (A. Ashtekar, D. Giuilini, J. Lewandowski, D. Marolf, J. Mourao, T. Thiemann, T. Strobl)
- *Black-hole entropy.* (T. Jacobson, K. Krasnov, D. Marolf, R. Myers, C. Rovelli)
- *Topological quantum field theories.* (J. Baez, M. Reisenberger)
- *String duality, conformal field theories.* (J. Fuchs, K. Meissner, R. Myers, T. Strobl)
- *Foundations of quantum mechanics and quantum cosmology.* (A. Ashtekar, D. Giulini, J. Halliwell, F. Embacher)

If participants were to single out one topic that generated most excitement, it would probably be the regularization of the Hamiltonian constraint by Thiemann. This has significantly deepened our understanding of the mathematical problems underlying quantum dynamics of general relativity. However, a number of important problems remain. In particular, during the program it was realized that these regularized quantum constraints have the feature that they strongly commute not only on diffeomorphism invariant states (which is to be expected physically) but also on a rather large class of states which are not diffeomorphism invariant (which is alarming from a physical viewpoint). A related potential difficulty is with the semi-classical limit: it is not clear if all the quantum constraints, taken together, admit a sufficient number of semi-classical states. Analogous calculations in 2+1 dimensions indicate that the appropriate semi-classical sector *does* exist. In 3+1 dimensions, further work is needed. This will no doubt be an area of much research and new effort in future years.

Hyperbolic systems with singularities

Organizers: P. Choquard, C. Liverani, D. Szász and H. Narnhofer (local organizer).

Total budget (including follow-up activities): ESI: ATS 711.700, external sources: ATS 192.000.

Dates: September – December, 1996.

Preprints contributed: [98], [298], [337], [382], [385], [387], [388], [409], [410], [412], [413], [414], [416], [423], [427], [429], [436], [437], [438], [442], [444], [445], [455], [468], [483], [489], [491], [504], [532], [543].

Report on the program by P. Choquard, C. Liverani and D. Szász

The program has focused on a broad range of problems connected with hyperbolic systems. Particular emphasis was given to the relation between dynamical systems and statistical mechanics. This was achieved thanks, in particular, to the composition of the participants of the program: a blend of mathematicians and theoretical physicists. In fact, the interaction among mathematicians and physicists was one of the main tasks of our activity. Another aim was to compare several new techniques recently put forward for studying dynamical systems, in the conviction that a synthesis and new insights were at hand.

In order to favor interaction among the participants we reduced officially scheduled talks to a minimum (one two-hour key-lecture per week) and asked people to otherwise self-organize talks and discussions. The intense activity and the wide involvement in interdisciplinary and specialistic discussions has rewarded such an approach.

The main fields of activity were: decay of correlations; ergodicity in infinite systems; dynamical problems in non-equilibrium statistical mechanics and ergodicity of hyperbolic systems with singularities.

The estimation of the rate of decay of correlations is not only interesting in itself but it has relevant physical implications for non-equilibrium statistical mechanics (e.g. Green-Kubo formulae). For long time it was known that smooth hyperbolic maps enjoy exponential decay of correlations for sufficiently smooth (Hölder) observables; yet, little was known beyond that (with the notable exception of one–dimensional systems and some partial results for billiards). Only recently substantial progress has been made: efficient techniques have been developed to treat systems with discontinuities (Liverani, Young, Benedicks), new ideas have been put forward to investigate the case of flows (Chernov, Dolgopyat), and some progress has been made in extending the Ruelle zeta–function formalism (Baladi, Keller, Rugh). Since almost all the above mentioned persons were present at the program it is not surprising that a lot of effort was put into comparing different points of view. Some of this effort has already produced concrete results ([413], [409]) but many of the projects and discussions initiated in Vienna are quite ample and ambitious, therefore not likely to crystallize in the very short term. Nevertheless, a very tight network of connections has materialized and it is bound to yield results for a long time.

Ergodicity in infinite systems is at the core of statistical mechanics but very few rigorous results are available. Yet, recently Bunimovich and Sinai proposed a model of coupled interacting maps that not only has been widely investigated numerically but has proven susceptible for rigorous analysis (Keller, Bricmont–Kupiainen, Pesin-Sinai, Jiang, ...). Quite a lot of attention was dedicated to such a model during our program. Up to now [388] is the only finished result but many new ideas have been advanced and, hopefully, new results are forthcoming.

A field in which the treatment of infinite systems is, at the moment, a prohibitive task, but a lot of progress have been made, is the case of hard balls interacting with elastic collisions. This has also been the subject of many discussions especially in view of the results of Simányi and Szász [337] that have made an important progress toward the understanding of the ergodicity of systems of hard spheres [98]. In fact, by using algebraic methods for complexified billiard dynamics, they could show that hard ball systems are fully hyperbolic for almost every parameters (masses, radii) of the model. This is a model in the domain of dynamical systems with singularities. On this subject many more arguments were discussed: e.g. Markov partitions (Krüger, Troubetzkoy), general billiards (Chernov, Markarian), one dimensional systems of balls (Wojtkowski), multidimensional billiards with convex boundary components (Bunimovich-Rehacek), bounds for the total number of collisions for hard ball systems in the euclidean space (Burago-Ferleger-Kononenko), that we hope will yield fruit in the near future.

Finally, a lot of effort was devoted to the study of the Lyapunov exponents both in Hamiltonian Systems [410] and in a class of systems that, currently, are receiving a great deal of attention: particles subject to an external force and in contact with a 'Gaussian thermostat' [414]. In this respect, it is interesting to notice that such systems have been recognized as Conformally Hamiltonian (on this subject a paper is in preparation) also thanks to discussions with some visitors of ESI (e.g. D. Alexeevski) not participating in our program. One of the many circumstances that underline the importance of the environment provided by ESI and the fruitfulness of bringing together scientists from seemingly unrelated fields.

Non-equilibrium statistical mechanics has been the main field of interest in the physics part of the programme. Typical subjects dealt with in individual research, group discussions, seminars — both spontaneous and officials — have been: Liapunov spectrum of the FPU-beta model in the infinite N limit (S. Ruffo); Kolmogorov-Sinai entropy and Liapunov spectrum of the Sinai model (H. van Beyeren), of the hard disk (R. van Zon) and hard sphere gas (H. Posch), of the low density field driven Lorentz gas (H. van Beyeren, J.R. Dorfman et al.); Gaspard-Nicolis escape-rate-formulas for transport coefficients (J.R. Dorfman), Liapunov exponents and transport coefficients (D. Evans); electric fields on a surface of constant negative curvature (F. Bonetto); thermostated systems (Ph. Choquard, H. Posch); dynamical systems and statistical mechanics (E.G.D. Cohen). Related problems connected with non-equilibrium statistical mechanics are the so called escape rates, either in finite systems [412] or in spatially extended systems [382]. This is one of the fields in which the interaction among physicists and mathematicians was especially lively.

Key lectures were given by Lai-Sang Young (*Decay of Correlations*), Stefano Ruffo (*Liapunov Spectra*), Leonid Bunimovich, P. Gaspard (*Chaos and Hydrodynamics*), N. Chernov (*Conditional Invariant measures. Mean free time and entropy for billiards*), E. Cohen (*Dynamical systems and statistical mechanics*), M. P. Wojtkowski (*Hamiltonian systems with linear potential and elastic constraints*) and G. Nicolis (*Non Equilibrium Thermodynamics of Dynamical Systems*).

Workshops organized outside the main programs

Winter school in geometry and physics.

Srni, January 13–20, 1996, Srní, Czech Republic, with a contribution of ATS 10.000 from ESI. The proceedings were published in Suppl. Rend. Circ. Mat. Palermo, II. Ser. **46** (1997), 9–176.

Contents:

Statistical mechanics as a branch of probability theory

This conference took place in Vienna, September 16-20, 1996, and was dedicated to the memory of Roland L. Dobrushin, who spent a significant part of his last years at ESI. ESI support was ATS 195.000. The conference resulted in the preprints [346], [347], [355], [360] and [384].

List of lectures:

Raghu VARADHAN: On the diffusive behavior of a tagged particle in the asymmetric simple exclusion models.
Konstantin KHANIN: Ground States for Random Burgers Equation.
Peter MAJOR: Existence and non-existence of phase transition in Dyson hierarchical model with continuous symmetry.
Alessandro PELLEGRINOTTI: Random walk in random environment.
Leonid BUNIMOVICH: Transport Coefficients from Dynamics.
Henk van BEIJEREN: Dynamical properties of disordered billiards.
József FRITZ: Ergodicity of infinite Hamiltonian systems with weak noise.
Yury SUHOV: Polygonal billiards with point obstacles.
Frank den HOLLANDER: Localization transition for a polymer near an interface.
Salvador MIRACLE–SOLE: Statistical mechanics of interface models.
Charles PFISTER: Wetting Phenomenon in the 2D Ising Model.
Miloš ZAHRADNÍK: A remark on the shape of the three dimensional Ising contours.
Lincoln CHAYES: Graphical representation.
Bogusław ZEGARLINSKI: Coercive Inequalities for Kawasaki dynamics.
Nobuo YOSHIDA: Relaxed criteria of Dobrushin-Shlosman mixing condition.
Enzo OLIVIERI: Renormalization-group at criticality and Dobrushin-Shlosman conditions.
Geoffrey GRIMMETT: Exponential decay for Potts and random-cluster models.
Hans-Otto GEORGII: Phase Transition for Continuum Potts Models.
Aernout van ENTER: Robustness of the non-Gibbsian property.
Eugene PECHERSKY: On applications of Gibbs fields in image processing.
Raphael LEFEVERE: Gibbs description of some non-Gibbs fields.
Herbert SPOHN: Stochastic particle systems (the one-dimensional asymmetric exclusion process).
Carlo BOLDRIGHINI: Navier-Stokes corrections for one-dimensional hard rods.
Alain MESSAGER: On the rigidity of the 1-1-1 interface in the Falicov-Kimball model.
Wolfgang SPITZER: On hydrodynamics of quantum hard rods.
Abel KLEIN: Griffiths singularity.
Christian MAES: Relaxation to equilibrium for glassy dynamics in the Griffiths' regime.
Fabio MARTINELLI: Relaxation of 2D disordered magnets in the Griffiths phase.
Arthur JAFFE: Hidden Symmetry.
Anatoly VERSHIK: Limit shapes in algebra & geometry and large deviations.
Boris GUREVICH: Thermodynamic formalism in the theory of infinite nonnegative matrices.
Robert MINLOS: Absence of phase transitions in quantum anharmonic crystal with light particles.
Valentin ZAGREBNOV: Quantum Fluctuations Can Suppress Structural Phase Transition.
Walter THIRRING: Spontaneously broken symmetries.

Satellite conference of the European Mathematical Congress: Aspects of spectral theory

This conference was organized by M. Hoffmann-Ostenhof, Th. Hoffmann-Ostenhof, H. Langer and R. Menniken. ESI contributed ATS 50.000 to the conference.

Lecture list: Heinz Siedentop (Oslo, Norway): Counting Eigenvalues Using Coherent States with an Application to Dirac and Schrödinger Operators in the Semi-Classical Limit.

Fritz Gesztesy (Columbia, Missouri, USA): Trace Formulas and Inverse Spectral Problems.

Michael Solomyak (Rehovot, Israel): Rozenblum-Lieb-Cwikel estimate for Markov generators.

Bernd Thaller (Graz, Austria): Optimal Norm Estimates for the Schrödinger Semigroup with a Magnetic Field in Two Dimensions.

Evgeni Korotyaev (St. Petersburg, Russia): The estimates and the inverse problem for the Hill operator.

Gunther Karner (Blacksburg, USA): The Schroedinger Equation on Time-Dependent Domains.

Andrea Sacchetti (Modena, Italy): Lifetime of Wannier-Stark resonance.

Y.M. Arlinskii (Lugansk, Ukraine): Closed sectorial sesquilinear forms and one-parameter contractive semigroups.

Zdzislaw Brzeźniak (Hull, Great Britain): Asymptotic Behaviour for Contraction Semigroups with Countable Unitary Spectrum.

Boris Pavlov (Auckland, New Zealand): Semigroup approach for Szegö-Kac determinants.

V. Kondratiev (Moskow, Russia/Potsdam, Germany): On estimate of the first eigenvalue of the elliptic operator.

Jürgen Voigt (Dresden, Germany): Schrödinger operators with singular complex potentials.

Serguei Naboko (St. Petersburg, Russia): On the absolutely continuous spectrum of the weighted discrete Schrödinger operators.

Lev A. Sakhnovich (Odessa, Ukraine): Spectral Problems (direct and inverse) for Canonical Systems.

Yaroslav Kurylev (Loughborough, Great Britain): Multidimensional Gelfand Inverse Problem with Complete and Incomplete Spectral Data.

Vyacheslav Pivovarchik (Odessa, Ukraine): Direct and inverse problems for an inhomogeneous string vibrating with damping and associated operator pencils.

Bernard Helffer (Paris, France): Witten's Laplacians and decay of correlations.

László Erdös (New York, USA): Semiclassics and Lieb-Thirring inequality for the Pauli operator in a strong nonhomogeneous magnetic field.

Ira Herbst (Charlottesville, USA).

A. Sobolev (Brighton, Great Britain): Quasi-classical asymptotics for the Pauli operator.

Mikhail Agranovich (Moscow, Russia): Nonsmooth elliptic boundary problems, transmission problems, and boundary problems with indefinite weight.

Rudi Weikard (Birmingham, USA): On Hill's Equation with a Singular Potential.

Simeon Vugalter (Nizhny Novgorod, Russia): Asymptotic estimates for bound states in quantum waveguides coupled laterally through a narrow window.

Grigorii M. Zhislin (Nizhny Novgorod, Russia): On the bound states of N-particle systems with large N in magnetic fields.

Andreas Fleige (Essen, Germany): A Counterexample to Completeness Properties for Indefinite Sturm-Liouville Problems.

Mel Faierman (Witwatersrand, South Africa): On a problem in fluid dynamics.

Alexander Kozhevnikov (Haifa, Israel): Spectral problems for differential operators of mixed order.

Georgi D. Raikov (Sofia, Bulgaria): Strong magnetic field spectral asymptotics for the Schrödinger operator.

József Benkö (Budapest, Hungary): Schrödinger equation of the hydrogen atom in strong magnetic fields.

Mark Michael Malamud (Donetsk, Ukraine): On the Gohberg and Krein's conjecture about cyclicity and unicellularity of Volterra operators.

Henk de Snoo (Groningen, The Netherlands): On a subdivision of Nevanlinna functions.

Sergei G. Pyatkov (Novosibirsk, Russia): Interpolation of some function spaces and indefinite Sturm-Liouville problems.

A. Sakhnovich (Odessa, Ukraine/Amsterdam, The Netherlands): Generalized Bäcklund-Darboux transform and transfer matrix function. Spectral and bispectral properties.

Aad Dijksma (Groningen, The Netherlands): Selfadjoint differential operators and one-dimensional form perturbations.

Robert Seeley (Newton, USA): Spectral asymptotics on a manifold with conic singular stratum.

Vladimir Mikhailets (Warsaw, Poland): Spectral Analysis of the One-Dimensional Schrödinger Operators with Point Interactions.

Pavel Kurasov (Bochum, Germany): Finite rank perturbations and selfadjoint extensions.

Branko Najman (Zagreb, Croatia): Singular perturbation of dynamical boundary value problems.

Vadim Adamyan (Odessa, Ukraine): Spectral Decomposition of Schroedinger Operator with Pauli Constraints.

Manfred Möller (Witwatersrand, South Africa): Differentiable dependence of eigenvalues of operators in Banach spaces.

Konstantin Makarov (Bochum, Germany): Three-body problem with point interactions: To Fall or not to Fall to the Center?

Franciszek H. Szafraniec (Kracaw, Polen): Limit procedures within the quantum harmonic oscillator.

Peter Stollmann (Frankfurt, Germany): Localization for random perturbations of periodic anisotropic media.

Mikhail A. Antonets (Nizhny Novgorod, Russia): Initial-boundary-value problems for hyperbolic systems with transmission and impedance conditions.

Yuri Tomilov (Kiev, Ukraine): On local and global asymptotic behavior of C_0-semigroup.

Nikolay D. Kopachevsky (Simfereopol, Ukraine): Hydrodynamical boundary eigenvalue problems with spectral parameter in an equation and boundary conditions.

Leonid Volevich (Moscow, Russia): Newton's polygon and the resolvent of a system elliptic in the sense of Douglis-Nirenberg.

Alexander Lifschitz (Chicago, USA): Preliminary results on the generalized Poincar'e problem.

Yurij M. Berezansky (Lublin, Poland): Infinite-dimensional non-Gaussian analysis and its applications to the operators of Schroedinger type.

Andrei A. Shkalikov (Moscow, Russia): Invariant Subspaces of Operator Matrices and Applications.

Christiane Tretter (Regensburg, Germany): Spectral Properties of the Orr-Sommerfeld Problem.

Reinhard Mennicken (Regensburg, Germany): Spectral decomposition of symmetric operator matrices and applications.

Vladimir Derkach (Donetsk, Ukraine): On generalized resolvents of symmetric relations in Krein spaces.

Seppo Hassi (Helsinki, Finland): Rank one perturbation of selfadjoint operators.

Michael Kaltenbäck (Vienna, Austria): A characterization of semibounded selfadjoint operators.

Abdelkader Intissar (Corte, France): Some New Properties of Regularity of the Shape Memory Alloys Operator.

Alexander Markus (Beer Sheva, Israel): On some properties of factorization indices.

Peter Jonas (Berlin, Germany): On the spectral theory of operator matrices and riggings.

Miroslav L. und Valentina I. Gorbachuk (Kiev, Ukraine): On entire Hermitian operators which admit a representation by partial differential operators.

Henrik Winkler (Dresden, Germany): Spectral problems for canonical systems and associated strings.

Jakov and Inna Roitberg (Chernigov, Ukraine): Green's formula for general systems of equations; Sobolev's problem in complete scale of Banach spaces.

Workshop on the changing Metaphysics of Science

This workshop was organized jointly by ESI and the 'Internationales Institut für Kulturwissenschaften in Wien'. ESI supported the stay of all physicists at this workshop with ATS 80.000. These were: John Ziman, Anton Zeilinger, John L. Heilbron, Lee Smolin, Sam Schweber, Carlo Rizutto, Jürgen Renn and Paul Forman.

Visitors outside the main programs

ESI spent ATS 444.000, with external contributions of ATS 347.000. The preprints [303], [312], [343], [300], [301], [374], [377], [396], [400], [401], [411], [296], [299], [304], [309], [310], [311], [314], [326], [356], [365], [395], [402], [403], [404], (405), [406], [419], [305], [358], [359], [383], [421] were contributed.

The year 1997

General remarks

Management of the Institute

President: Walter Thirring
Director: Peter Michor
Deputy Director: Jakob Yngvason
Administration: Lilla Hartyani, Anna Maria Ojeda
Computers: Andreas Čap, Hermann Schichl

International Scientific Advisory Committee

Jean-Pierre Bourguignon (IHES)
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Klaus Schmidt (Vienna)
Domokos Szasz (Budapest)

Budget and visitors: The budget of ESI for 1997 was ATS 9,6 Mio (€697.700). About ATS 3,8 Mio were spent on scientific activities and ATS 5,8 Mio on administration, infrastructure, and some left-over bills for the adaptation of the building. Visitors supported from other sources contributed the equivalent of a further ATS 1,12 Mio.

The number of scientists visiting the Erwin Schrödinger Institute in 1997 was 242, and the number of preprints produced was 105.

Programs in 1997

Ergodic theory and dynamical systems

Organizers: A. Katok, G. Margulis and K. Schmidt.

Total budget (including follow-up activities): ESI: ATS 995.000, external sources: ATS 550.000.

Dates: January – August, 1997.

Preprints contributed: [424], [425], [428], [433], [439], [484], [494], [497], [503], [519].

Report on the program by A. Katok and K. Schmidt

This program was devoted to the study of Dynamical Systems, with special emphasis on multidimensional dynamics and the new phenomena encountered there, as well as on the interaction between Dynamical Systems and Number Theory, Geometry and Statistical Mechanics.

The program started in January 1997 with a series of lectures by D. Rudolph on *Entropy theory and restricted orbit equivalence for discrete amenable group actions,* in which he presented recent joint work with J. Kammeyer on entropy as a complete invariant of (suitably) restricted orbit equivalence. K. Park lectured on her work on *Subdynamics of $\mathbb{Z}^d$-actions,* J.-P. Thouvenot and E. Glasner presented results on the *Pinsker algebra of product actions and joinings,* and Ya. Pesin gave two lectures on *Spatio-temporal chaos in coupled map lattices* (a class of $\mathbb{Z}^2$-actions arising in statistical mechanics). Amongst the topics of further lectures in January were *Notions of complexity of dynamical systems* (S. Ferenczi) and *Recent progress in billiards* (A. Stepin). Lectures by A. Katok on *Conjugacy rigidity of hyperbolic maps with sufficiently large commutants* and K. Schmidt on *Homoclinic points and Markov partitions of algebraic $\mathbb{Z}^d$-actions* served as an introduction to one of the main topics of the February Conference on *Ergodic Theory, Geometry and Arithmetic*: the rigidity properties of higher rank abelian group actions.

February was dominated by the two-week **Conference on Ergodic Theory, Geometry and Arithmetic,** February 3-14, 1997, organized by A. Katok and G. Margulis. The main theme of this very intensive meeting was the comparison of 'arithmetical' rigidity properties of actions of 'large' groups, like Kazhdan groups, and the 'geometrical' rigidity properties appearing in actions of higher-rank abelian groups, like $\mathbb{R}^d$ and $\mathbb{Z}^d$, or, for example, in the geometric structure at infinity of Riemannian manifolds of negative and non-positive curvature.

In addition to almost thirty research talks (listed below) there were five major survey lecture series:

1. Eskin, Kleinbock, Margulis, and Shah gave six lectures on flows on homogeneous spaces and number theory, in which they presented connections between arithmetical results connected with the Raghunathan conjecture and its solution, and striking new results on diophantine approximation and related questions.

2. Katok and Schmidt gabe a series of four lectures on actions of higher-rank abelian groups and rigidity, in which they presented a variety of rigidity results (such as cohomological rigidity, isomorphism rigidity, perturbation rigidity and scarcity of invariant measures) for geometric and algebraic actions of $\mathbb{Z}^d$ and $\mathbb{R}^d$ with $d \geq 2$.

3. Burger and Mozes gave three lectures on lattices in the automorphism group of a product of trees in which they presented new results and examples both in the theory of infinite groups and in multidimensional shifts of finite type.

4. Besson and Courtois described their landmark results on the geometry of manifolds with geodesic flows of minimal entropy in three lectures.

5. Feres gave three lectures on topological superrigidity which centered around his joint work with Labourie on cocycle superrigidity in the absence of invariant measures.

Further talks in the Conference in ergodic theory, geometry and arithmetic:

M.Ya.Antonovskii: 1965 School in Ergodic Theory at Humsan, Uzbekistan. Reflections and recollections of the organizer.
A.Katok: Ergodic theory from Humsan to Vienna.
H. Furstenberg: Stiffness of group actions.
G. Knieper: Volume growth and the distribution of closed geodesics in manifolds of nonpositive curvature.
B.Leeb: Groups quasi-isometric to symmetric spaces.
B.Farb: Quasi–isometry and rigidity: latices and beyond.
E.Ghys (ENS-Lyon): Smooth linearizations of $SL(n)$-actions around a fixed point.
I.Benoist (Paris VII): Linear groups with positive eigenvalues.
G.Tomanov (U.Lyon): On the quadratic and unitary inequalities in the S-adic case.
P.Foulon (Strasbourg): Dynamical rigidity in Finsler geometry.
V.Kaimanovich (Rennes): Singularity of the harmonic measure on symmetric spaces.
H. Abels (Bielefeld): A quantitative version of finite generatedness for lattices.
W.Ballmann (Bonn): Property T for groups acting on complexes.
U.Hamenstaedt (Bonn): Cocycles, cross-ratios and eigenfunctions in negative curvature.
F. Grunewald (Dusseldorf): On ternary quadratic forms.
P de la Harpe (Geneva): Growth on root lattices and Ehrhart polynomials.
I.Goldsheid (London): Zariski dense semi-groups of Lie groups: properties of eigenvalues and invariant sets.
A.Starkov (Istra): Closures of horospherical leaves on hyperbolic manifolds.
G.Soifer (Bar-Ilan): Discontinuous groups of affine transformations with orthogonal linear part.

S.Katok (Penn State): Automorphic forms of the complex hyperbolic space.
S.Hurder (Illinois-Chicago): Boundary Chaos for open manifolds.
S.Adams (Minnesota): Dynamics on Lorentz manifolds.
C-B.Yue (Penn State): On the representation variety of complex hyperbolic Kleinian groups.
Y. Gao (Yale): Superrigidity for isometric group actions on CAT(-1) spaces.
A.Torok (Princeton): Regularity and rigidity of cocycles.
V.Nitica (Indiana): Cocycles over Anosov actions.
N.Qian (Yale): Tangential flatness and local rigidity of higher rank lattice actions.
A.Wilkinson (Norstwestern): Prevalence of non-Lipschitz Anosov foliations and conjugacies.
E.Gutkin (USC): Polygonal billiards and cofinite lattices.

The conference was attended by most of the active researchers in the subject, both at senior and at junior level.

After mid-February things quietened down a little. G. Margulis and A. Katok gave surveys of *Flows on homogeneous spaces and Diophantine approximation on manifolds* and *Hyperbolic measures,* respectively, M. Lemanczyk presented current work on *Gaussian processes,* and T. Ward gave an account of recent work on *S-integer dynamical systems* which again show a remarkable interplay between arithmetic and dynamics. One should also mention C. Radin's visit in May, during which he spoke on the symmetry properties of some of the remarkable planar tilings he and others have constructed. Research on *Voronoi tilings* was presented by N. Priebe.

With the beginning of June the number of visitors increased again and the emphasis of the programme shifted towards symbolic dynamics. Although the classification of automorphisms and homomorphisms of shifts of finite type is part of mainstream symbolic dynamics, any such classification sheds light on the multidimensional shifts of finite type generated by the shift and suitable shift-commuting automorphisms. Here the main result presented during this part of the conference was the *Counterexample to the Williams conjecture* due to Kim and Roush, which was investigated in detail and subsequently described in a series of lectures by M. Boyle. S. Tuncel presented new results on the *Classification of Markov endomorphisms,* which were joint work with B. Marcus.

Amongst many further results connected with symbolic $\mathbb{Z}^d$-actions one should list D. Lind's lecture on *Milnor's entropy geometry and algebraic $\mathbb{Z}^d$-actions,* J. Steif's investigation of *Higher-dimensional T, T^{-1}-systems,* in which he proved Bernoullicity of varying degrees (depending on the dimension) in dimension ≥ 3, B. Kamiński's study of *Invariant sigma-algebras of multi-dimensional processes* and E.A. Robinson's lecture on *The Krieger representation theorem for a class of multidimensional shifts of finite type.*

A number of visitors to the program worked on and presented results in areas of Dynamics not specifically related to multiparameter ergodic theory. M. Keane gave a beautiful elementary proof of *Birkhoff's classical ergodic theorem,* V.F.R. Jones spoke on *Planar algebras,* which have some very intriguing connections with Wang tiles (hence with two-dimensional shifts of finite type) and Bratteli diagrams (hence with interval exchange transformations), there were two lectures on the general concept of *Randomness* (by V. Sós and K. Petersen), J. Feldman and M. Smorodinsky presented new results on *Standard and nonstandard processes* (a problem connected with the classification of decreasing families of sigma-algebras), and Y. Kifer explained work on *Computations in chaotic dynamics via random perturbations.* Two participants investigated noncommutative dynamical systems (S. Bezuglyi and T. Hamachi), and S. Williams and D. Silver worked on *Applications of Symbolic Dynamics to Knot Theory.* A number of visitors studied dynamical properties of arithmetical expansions (Aaronson, Johnson, Nakada, Shelton, Yuri), or formal languages (D. Fiebig, U. Fiebig and W. Krieger).

This list of research topics and lectures is far from exhaustive, but should give an indication of the direction and breadth of the program. A further feature of the program was the exceptionally high financial contribution to the program from outside sources, including USD 3000 from the Dynamical Systems Research Center at Penn State University for additional support of postdocs.

Mathematical relativity

Organizer: R. Beig.

Total budget (including follow-up activities): ESI: ATS 417.000, external sources: ATS 66.000.

Dates: January – June, 1997.

Preprints contributed: [467], [460], [475], [507], [515], [524].

Report on the program

The work in this program was devoted to the study of analytical and geometrical problems related to - mostly classical - aspects of the Einstein Equations (EE's).

V. Moncrief worked out higher order energies of the so-called Bel-Robinson type which play a crucial role in global existence proofs for the Vacuum Einstein Equations (VEE's). These calculations are part of a long-term project, with L. Andersson, on solutions of the VEE's on manifolds of the form $M \times R$, with M a compact hyperbolic space. The aim is to prove stability of the flat solutions of this form, obtained as a certain quotient of (the interior light cone of a point of) Minkowski space. Such a result would be a cosmological analogue of the celebrated theorem, due to Christodoulou and Klainerman, on the nonlinear stability of Minkowski space.

A. Fischer and V. Moncrief continued their collaboration on ADM reduction. They proved that the only critical points of the reduced Hamiltonian (on compact manifolds of negative Yamabe type) are Cauchy data for the expanding, flat hyperbolic models from above.

V. Moncrief and J. Nelson continued work involving the quantized $2+1$-EE's (with a cosmological constant) on $T \times R$, with T a 2-torus.

R. Beig and N. 0'Murchadha studied the maximal slicing of the extended Schwarzschild spacetime. They gave rigorous estimates of the decay of the lapse function as the last maximal slice is approached.

E. Malec and N. O'Murchadha worked on the spherically symmetric Einstein-Massless Scalar Field system. In particular they found rigorous estimates for the influence of the phenomenon of backscattering on the intensity of the outgoing radiation.

R. Beig and L. Szabados found a conformal invariant of initial data sets on compact 3-manifolds. This invariant, in the special case of totally geodesic initial data sets, reduces to the one of Chern and Simons. The behaviour of this invariant under evolution of initial data sets by the EVE's will be studied in the future.

R. Beig and B. Schmidt looked at some open issues in the asymptotic structure of stationary vacuum spacetimes. Their results formed part of a subsequent review article on stationary spacetimes they are in the process of writing.

There was a lively interaction among participants of the workshop and, moreover, with the participants of the parallel program on CR structures, organized by L. Mason, P. Nurowski and H. Urbantke.

Spaces of geodesics and complex structures in general relativity and differential geometry

Organizers: L. Mason, P. Nurowski, H. Urbantke.

Total budget (including follow-up activities): ESI: ATS 579.500, no external contributions.

Dates: March, April and June, July 1997.

Preprints contributed: [432], [434], [451], [461], [464], [470], [471], [477], [486], [487], [493], [505], [516], [518], [520]; [521], [522], [535], [590], [624]. 1999: [731], [734], [735], [739]. 2000: [821], [863]. .

Report on the program

The program consisted of two interrelated parts. The first focussed on application of spaces of null geodesics to general relativity and second to problems in differential geometry.

1) Particular attention was paid to analytic subtleties associated with the Robinson theorem. The theorem in its original version says, in particular, that if a space-time $\mathcal{M}$ admits a congruence of shear-free and null geodesics k then there exists a null Maxwell field associated with k in $\mathcal{M}$. Discussing this T. Bailey, D. Hill, L. Mason, P. Nurowski, I. Robinson, G. Sparling, J. Tafel, A. Trautman, H. Urbantke found examples of nonanalytic but smooth congruences of shear-free and null geodesics which

do not admit any solution to the Maxwell equations for the associated null 2-form. This means that the Robinson theorem as quoted above needs some additional assumptions (e.g. analyticity or realizability) as conjectured by Tafel in 1985. Our examples were based on the relation between congruences of null geodesics and 3-dimensional CR-manifolds associated with them. The main arguments in the construction of the examples are as follows.

a) Suppose we have a shear-free congruence of null geodesics in space-time, such that its associated CR-structure admits a nonconstant solution to the tangential CR-equation. Then there exists a null Maxwell field associated with the congruence if and only if there exists a second independent solution to the tangential CR-equation.

b) Given a three-dimensional CR-manifold $\mathcal{Q}$ with a smooth CR-structure it is straightforward to associate with it a 4-dimensional Lorentzian manifold (space-time) in which there exists a smooth congruence of shear-free and null geodesics which has $\mathcal{Q}$ as its CR-manifold.

c) Rosay constructed smooth CR-structures on 3-manifolds that admit only one nonconstant solution to the tangential CR-equation.

Combining a), b) and c) we concluded that any of Rosay's CR-structures give rise to a congruence of shear-free and null geodesics in a space-time which does not admit an associated null Maxwell field.

The following related problem was not solved: Suppose that we have a congruence whose corresponding CR-structure does not admit any nonconstant solution to the tangential CR-equation. Is it possible to associate a null Maxwell field to such a congruence? Since the situation is even worse than in the case a) it is very likely that the answer is no - but the participants were unable to prove it. This is the only other alternative to the case discussed above and the realizable case for which Robinson's theorem can be seen to work in a straightforwardly.

A. Trautman summarized the above in the following **conjecture**: A congruence of shear-free and null geodesics in space-time defines a null Maxwell field if and only if its associated CR-manifold is locally embeddable in $\mathbb{C}^2$.

There were also discussions concerning the problem of an existence of nonanalytic congruences in Minkowski space-time. Although there were lively discussions between D. Hill, G. Sparling, J. Tafel and H. Urbantke, the issue was not resolved.

This part of the activity was concluded by a series of lectures by G. Sparling on CR-structures in physics.

2) Algebraically special space-times naturally fitted to the project since, due to the Goldberg-Sachs theorem, these are the only Einstein space-times that admit congruences of shear-free and null geodesics. L. Mason and J. Tafel presented two views on global properties of such space-times. Mason proved that the only algebraically special space-time which is asymptotically simple is Minkowski space. A paper by J. Tafel and S. Pukas were (then) in preparation and one by L. Mason had already been submitted as an ESI preprint and will appear in Classical and Quantum Gravity.

Global properties of space-times were also discussed by J. Beem, who pointed out that horizons may not be differentiable, and that such pathologies can exist even on dense subsets of the horizon.

A different problem was discussed by R. Low who studied singularities of wave fronts. It relates to the work of E.T. Newman and S. Frittelli who encountered such problems in their Null Surface Formulation of General Relativity.

L. Szabados gave a review of definitions of gravitational energy and J. Frauendiener derived an integral formula on hypersurfaces in space-time that unifies integral form of Raychauduri equation for null congruences and Bondi mass loss formula. They were collaborating with the participants of the parallel workshop organized by R. Beig. Also P. Tod used this opportunity in preparation of his review of Mathematical Relativity.

3) Reformulations of the 4-dimensional Einstein equations in the spirit of twistor theory were discussed. The persons involved in the discussions were: S. Fritelli, J. Lewandowski, L. Mason, T. Newman, P. Nurowski, R. Penrose, D. Robinson, G. Sparling, J. Tafel, P. Tod, A. Trautman, H. Urbantke.

The activity included a series of lectures by R. Penrose on twistors in curved space-times, followed by G. Sparling's lectures on his abstract twistor spaces for the Einstein (not anti-self-dual) space-times. In particular, Sparling (and Z. Perjes) constructed abstract twistor spaces for Einstein space-times with six symmetries (and for the Schwarzschild solution).

P. Nurowski developed formulation of the Einstein equations on the bundle of null rays over the space-time and its double branch cover. This formulation is based on an attachment of a (possibly degenerate) elliptic curve to each point of the space-time. In particular, the formulation gives a new view on the Petrov classification, since the degeneracies of the principal null directions at the space-time point correspond to the degeneracies of the elliptic curve attached to this point.

This formulation was compared with the Null Surface Formulation of General Relativity of T. Newman and his collaborators. A joint paper of Fritelli, Lewandowski, Newman and Nurowski about these relations is being prepared.

D. Robinson developed his chiral action formulation of the vacuum Einstein equations.

L. Mason and J.-P. Nicolas completed their paper 'Global solutions of the Rarita-Schwinger equations and the Einstein equations' in which analytic results about the Rarita-Schwinger equations are proved and their connections with the Einstein equations are discussed. This was also lectured on by L. Mason and will be presented as an ESI preprint.

4) There were discussions on integrable systems. This relatively new field of applications of twistor theory had a strong representation during the workshop. The people involved were: J. Armstrong, M. Dunajski, L. Mason, P. Nurowski, M. Przanowski, G. Sparling, J. Tafel, P. Tod, N. Woodhouse.

M. Dunajski and L. Mason worked on their twistor construction of anti-self-dual hierarchies. M. Przanowski presented his joint work with J. Plebański which gave a differential equations aspect of the same problem.

In a series of lectures, M. Przanowski presented his results on algebraically special Einstein 4-manifolds with positive definite metric. The results were used by Nurowski and Przanowski to construct a 4-dimensional example of Ricci flat metric admitting almost-Kähler non-Kähler structure. The nonconstructive proof that such examples exist was presented by J. Armstrong. This is surprising in view of the result of K. Sekigawa who proves that under the assumption of compactness of the Einstein manifold every almost-Kähler structure is Kähler.

P. Tod presented his work on 4-dimensional Einsteinian D'Atri spaces, proving that they are locally symmetric. This was conjectured by Sekigawa and Vanhecke some time ago.

J. Tafel completed his joint work with D. Wójcik on null Killing vector reductions of the Yang-Mills equations in flat 4-manifold with metric of neutral signature.

5) P. Kobak and P. Nurowski worked on the Lorentzian counterpart of the twistorial construction of harmonic maps. The paper on this was prepared in collaboration with M. Bobieński, and was discussed with P. Gauduchon, A. Trautman and S. Salamon.

Suggestions for subsequent activity. Not all the aims of the project were achieved. Some topics listed in the project description were not touched on at all, mainly because some of the invited guests could not come to ESI.

On the other hand there are also topics which require further elaboration. These include (we list the topics with the associated persons in the proposal): non-analytic congruences in Minkowski space (Sparling, Tafel, Urbantke), global properties of algebraically special solutions (Mason, Tafel), relations between null surface formulation of GR and elliptic fibrations (Fritelli, Newman, Nurowski), twistor formulation of anti-self-dual hierarchies (Dunajski, Mason), Lorentzian counterpart of the twistorial harmonic maps construction (Nurowski, Kobak), Twistor approaches to the Einstein equations (Mason, Nicolas).

Local quantum physics

Organizers: D. Buchholz, H. Narnhofer and J. Yngvason.

Total budget (including follow-up activities): ESI: ATS 883.000, external sources: ATS 435.000.

Dates: September – December, 1998.

Preprints contributed: [446], [448], [449], [469], [496], [498], [499], [501]; [525], [528], [529].

Report on the program

Part of the program was the

Workshop on local quantum physics. This workshop was organized for the week September 29 - October 4, 1997.

Lectures given:

R. Haag (Neuhaus/Schliersee): Objects, events and localization in quantum theory.
R. Stora (Annecy): Memories about renormalized perturbation theory.
K. Fredenhagen (Hamburg): Local (perturbative) construction of interacting fields on curved spacetime.
I. Ojima (Kyoto): Spontaneous collapse of supersymmetry.
H. W. Wiesbrock (Berlin): On modular theory and its application to physics.
J. Roberts (Rome): New directions in superselection theory.
O. Steinmann (Bielefeld): Particles as localized objects in quantum field theory.
S. Doplicher (Rome): On the C^*-algebra of a Hilbert bimodule.
M. Müger (Rome): Superselection structure of massive quantum field theories in $1 + 1$ dimensions.
K. H. Rehren (Hamburg): Statistics and modular theory of solitons.
H. J. Borchers (Göttingen): On the embedding of von Neumann algebras.
B. Schroer (Berlin): Modular localization, H-temperature and bootstrap formfactor program.
D. Guido (Rome): Superselection structure of conformal nets and applications to quantum field theories in curved spacetimes.
S. Summers (Gainesville): Geometric modular action and spacetime symmetry groups.
M. Wollenberg (Leipzig): An inverse problem in modular theory.
E. Seiler (Munich): Continuum limits of spin models and local cohomology.
F. Strocchi (Pisa): Fermion boundary conditions and vacuum parameters.
N. Landsman (Cambridge): Theta-angles and anomalies in QFT.
G. Morchio (Pisa): Generalized Weyl systems.
U. Moschella (Como): De Sitter quantum field theory: Introduction and applications.
F. Bros (Saclay): Quantum field theory in de Sitter universe.
B. S. Kay (York): Quantum fields in non globally hyperbolic spacetime.
H. Grosse (Vienna): Simple field theoretical models on non-commutative manifolds.
W. Junker (Potsdam): On a Euclidean approach to QFT on curved spacetimes.
R. Verch (Göttingen): On wavefront sets and algebraic quantum field theory.
R. Conti (Rome): On sectors with infinite statistics.
C. D'Antoni (Rome): Extension of antiautomorphisms and the PCT symmetry.
T. Matsui (Fukuoka): Classification of positive energy representations for massive lattice models.
K. Baumann (Göttingen): On bounded Bose fields in 1+1 dimensions commuting for space- and time-like distances.

More than 30 experts for the structural analysis in relativistic quantum field theory participated in this 3 month project at ESI and worked together on about 5 different but interrelated topics. The program was centered about an intense one-week workshop to which further researchers were invited. Beside it between 2 and 4 more informal talks were delivered each week by participants on an ad hoc basis. The topics covered in this project range from the structural analysis of nets of local algebras through problems in the theory of superselection sectors and thermal quantum field theory to quantum field theory on curved spacetime. In spite of this diversity of problems there appears to be an almost universal mathematical tool for their treatment: modular theory. This intriguing fact was the leading theme in this project and its deeper understanding was one of the central goals. The results obtained provide further evidence to the effect that modular theory is a primary key to the understanding of local quantum physics. In the following an outline is given of the specific problems treated and results obtained by the participants of the project.

a) Modular theory, local algebras and spacetime symmetries. The relation between the modular operators appearing in quantum field theory, the lattice structure of local algebras of wedge-like regions and the and spacetime symmetries was discussed by by H.J. Borchers, D. Buchholz, D. Guido, B. Kuckert, H. Rehren, B. Schroer, S.J. Summers, S. Trebels, E.H. Wichmann and J. Yngvason.

H. Borchers worked on the question under which circumstances the modular groups associated with algebras of wedge–like regions coincide with the Poincaré transformations. Discussions with D. Buchholz, S. Summers and I. Todorov helped to isolate obstructions to this coincidence and led H.J. Borchers to a new characterization of theories with a unique representation of the Poincaré group. In another project H.J. Borchers and J. Yngvason investigated the structure of the modular groups which are associated with cone-like regions in representations induced by temperature states. For a class of chiral theories they were able to show that these groups still have an interpretation as (local) spacetime symmetries.

D. Buchholz and S.J. Summers continued during this project their investigation of the role of the modular conjugations in quantum field theory. Discussions with E.H. Wichmann led them to a more stringent formulation of their condition of geometric modular action which is designed to characterize preferred (vacuum like) states on a large class of spacetime manifolds. The latter aspect of this work has triggered stimulating (partly controversial) discussions with J. Bros, K. Fredenhagen, B. Kay, U. Moschella and R. Verch. The results obtained so far seem to indicate that at least for spacetimes with a sufficiently big isometry group the aforementioned condition serves its purposes. These results will soon appear as ESI preprint.

B. Kuckert was able to improve his recent uniqueness theorem for modular symmetries by making use of a (yet unpublished) result of S. Trebels which he learned from the author during the workshop. H.J. Borchers, D. Guido and E.H. Wichmann were also involved in the discussions of this problem.

H. Rehren worked on modular theory in low-dimensional field- theoretic models, primarily for soliton sectors, and established an interpretation of the CPT and Spin-Statistics-Theorem in terms of the associated modular structures.

Finally, B. Schroer presented some intriguing ideas on the reconstruction of local algebras in interacting theories from free fields by introducing the notion of modular Møller operators. This novel approach to the so-called formfactor program seems to deserve a more detailed mathematical analysis.

b) Superselection structure and statistics. The second major topic of this project was the analysis of the superselection structure in case of quantum field theories which do not fit into the so-called DHR-setting, either because of the presence of long range effects or because of the structure of the underlying spacetime manifold. Various aspects of this circle of problems were treated by C.D'Antoni, D. Buchholz, S. Doplicher, D. Guido, G. Morchio, H. Rehren, J.E. Roberts, V. Schomerus, F. Strocchi, S.J. Summers, I. Todorov and R. Verch.

C.D'Antoni, S.J. Summers and R. Verch began a general study of the sector structure at short distances by using the method of the scaling algebra. There is some hope to establish criteria by which one can decide whether in a given theory charged sectors appear or disappear in the scaling limit (compare the confinement problem).

In a joint project D. Buchholz, S. Doplicher, G. Morchio, J.E. Roberts and F. Strocchi aimed at clarifying the localization properties of charged states in quantum electrodynamics. To this end an analysis of the classical Dirac-Maxwell theory, perturbative computations and a formal discussion in the indefinite metric formalism were carried out. The conclusion was that there is no obvious algebraic obstacle to localizing charged states on the algebra generated by the charge density and the magnetic field in a given Lorentz system. Since a mathematically satisfactory treatment of full quantum electrodynamics has not been accomplished yet, more rigorous results seem presently out of reach. But the above findings support an old conjecture of J. Fröhlich according to which the electric charge has better localization properties than normally assumed. The present findings seem to be the key to a general structural analysis of the charged superselection sectors in abelian gauge theories.

In a closely related project D. Buchholz, S. Doplicher and J.E. Roberts analyzed the question in which sense a particular type of charge is localized. They concluded that any charge has a canonical localizing net, i.e. a net on which it is localized. The size of this localizing net is then a measure of how well the charge in question can be localized. They also established conditions on the localizing net which allow one to generalize standard results from the theory of superselection sectors.

J.E. Roberts also worked with D. Guido, B.S. Kay and R. Verch on superselection sectors and the connection between spin and statistics in quantum field theories on curved spacetime.

Problems related to the superselection structure of theories in low dimension were treated by H. Rehren (cf. above) and in a collaboration of V. Schomerus and I. Todorov. The latter project concerns braid group properties and fusion rules for chiral WZNW models and relates the current work of V. Schomerus and A. Alekseev with earlier work of Y. Stanev and I. Todorov.

c) Thermal states. The rigorous structural analysis of thermal states in relativistic quantum field theory is receiving increasing attention in recent years and was also discussed by several participants of this project (H.J. Borchers, J.Bros, D. Buchholz, Ch. Jäkel, I. Ojima, J. Yngvason).

The work of H.J. Borchers and J. Yngvason on the geometrical significance of the modular structure in case of thermal states was already mentioned. One may expect that these results will stimulate further investigations of this unexpected feature of thermal states.

The concept of 'Goldstone particle' in thermal quantum field theory was studied by J. Bros and D. Buchholz. It was recognized that the decrease properties (in spatial variables) of the so-called damping factor in a Källèn-Lehmann type representation of thermal current-field correlation functions is strongly correlated with the possible occurrence of a Goldstone particle in the thermal bath. This observation may be the key to a more satisfactory understanding of the spectral implications of the spontaneous breakdown of symmetries in thermal states.

The general mathematical structure of thermal states in relativistic quantum field theory was studied by Ch. Jäkel. Discussions with J. Bros, D. Buchholz, I. Ojima and J. Yngvason helped to clarify various technical points which appeared in this analysis. It seems that prominent features of the vacuum sector, such as the Reeh-Schlieder and the split property can also be established in thermal states.

The physical role of the center variables in thermal and vacuum states has been the research topic of I. Ojima who worked on the relation between the nature of the fluctuations of order fields, low energy theorems and the large deviation principle. Discussions with D. Buchholz, S. Doplicher, N. Landsman and J.E. Roberts lead to the clarification of certain group theoretic aspects of the problem which are related to the partial spontaneous breakdown of symmetries.

d) Quantum field theory on curved spacetime. Recently there has been much progress in the characterization of elementary physical states on curved spacetime manifold and a substantial part of this project was devoted to this topic. The following participants were actively involved in these discussions: H.J. Borchers, J. Bros, D. Buchholz, S. Doplicher, H. Fredenhagen, B. Kay, U. Moschella, S.J. Summers, R. Verch.

J. Bros and U. Moschella continued their collaboration on problems related to quantum field theory on (anti) de Sitter spacetime. They made significant progress on the Fourier-Laplace analysis on these spaces from the viewpoint of classes of holomorphic functions in appropriate tuboid domains. This is an important ingredient in their program of constructing field propagators on holomorphic spaces. Discussions with H.J. Borchers, D. Buchholz and S.J. Summers dealt with the relation between the principle of maximal analyticity of J. Bros and U. Moschella and the condition of geometric modular action (cf. above) and modular covariance. They stimulated an investigation of global properties of vacuum-like states on de Sitter space by H.J. Borchers and D. Buchholz. Another interesting issue which was discussed is the relation between the holomorphic approach of J. Bros and U. Moschella and the wave-front set condition of R. Brunetti, K. Fredenhagen and M. Radzikowski.

S. Doplicher and K. Fredenhagen analyzed in which sense the local algebras of free massive fields in their basic model of quantum spactime deform to the usual local algebras on Minkowski space if the Planck length is treated as a parameter tending to zero, while the mass of the field is fixed. Interesting partial results emerged, although the problem turned out to be unexpectedly subtle.

The question of the existence of a local vacuum for quantum fields in curved spacetime was addressed by B. Kay. The point of view which he adopts in his approach to characterize preferred states is very different from the principle of geometric modular action proposed by D. Buchholz and S.J. Summers. There has been a very stimulating and encouraging exchange of ideas on this issue. B. Kay also discussed with R. Verch the question as to how one might possibly weaken the Hadamard condition for linear quantum fields in curved spacetime while maintaining local quasi-equivalence.

e) Concepts and constructive methods. Besides the work addressed to the above specific issues there has been a fruitful exchange on general conceptual and constructive problems amongst the participants of this project, especially K. Baumann, J. Bros, M. Dubois-Violette, R. Haag, H. Narnhofer, D. Schlingemann, E. Seiler, O. Steinmann, R. Stora and E.H. Wichmann.

The intriguing ideas of R. Haag on a reformulation of quantum theory based on the concept of 'event' were discussed both in seminars and in many private conversations. It would be desirable to develop an appropriate mathematical setting which allows one to formalize these physically attractive ideas.

K. Baumann worked on the existence of so-called bounded Wightman fields, a question raised originally by J. Yngvason. His results, which partly emerged in conversations with H. Rehren, provide strong evidence to the effect that bounded Wightman fields in two spacetime dimensions which commute at space- and timelike distances are sums of p-products of chiral Fermi fields.

The problem of the relation between the Wightman framework of quantum field theory and the algebraic setting was discussed by H. Narnhofer and E.H. Wichmann. Special attention was given to the question whether every subnet of a local net of von Neumann algebras which is generated by Wightman fields can also be regarded as generated by (possibly multi-variable) fields. An affirmative answer to this question seems within reach.

An interesting approach towards the direct construction of local $C*$-algebras by Euclidean methods was completed by D. Schlingemann during this project. Discussions with J. Bros, E. Seiler and J. Yngvason helped to settle various technical points which had appeared in this work.

O. Steinmann worked on a justification of the perturbative construction of quantum electrodynamics by methods of axiomatic field theory. His treatment of the infraparticle problem stimulated a general discussion of the particle concept in theories with long range forces.

R. Stora commented on an approach *a la* Epstein-Glaser towards the perturbative construction of non-abelian gauge theories which has been put forward by the group of G. Scharf in Zürich. He pointed out that some apparent cohomological obstructions ought to be checked and M. Dubois-Violette was able to show that there are no such problems. This conceptually surprisingly simple approach seems therefore quite promising.

The use of geometrical methods of analytic completion versus the Dyson wave equation method for determining the null regions of commutator functions was discussed by H.J. Borchers, J. Bros, D. Buchholz, R. Stora and E.H. Wichmann. It turned out, much to the surprise of the experts, that for certain non-standard regions the Dyson method gives stronger results than the analytic techniques.

Finally, problems appearing in renormalization theory triggered a discussion between J. Herman, B. Kuckert, M. Oberguggenberger and I. Todorov on the application of new types of generalized functions (Colombeau-framework) to problems in constructive quantum field theory.

The preceding outline of activities reveals the broad spectrum of problems treated and the many interrelations between the various subjects. The fact that more new intriguing questions were raised during this project than answered provides evidence of the stimulating and fruitful atmosphere at ESI. It is to be expected that a substantial part of the ongoing projects mentioned above will be finished within a few months and will result in further ESI-publications. There was unanimous agreement that this intensive exchange between experts working in quite different areas will have substantial impact on the future development of local quantum physics.

Nonlinear theory of generalized functions.

Organizers: M. Oberguggenberger, M. Grosser and M. Kunzinger.

Total budget (including follow-up activities): ESI: ATS 571.500, external sources: ATS 124.000.

Dates: September – December 1997.

Preprints contributed: [502], [508], [511], [512], [513], [531], [533], [558], [565], [566], [627], [653], [666] [811], [812], [813], [814], [815], [829], [837].

Report on the program by M. Oberguggenberger

The aim of the project was to develop applications of the nonlinear theory of generalized functions to various fields in mathematical analysis and mathematical physics, and in particular, to investigate the interplay of nonlinearity and creation and propagation of singularities in models involving differential equations and generalized functions. The project proceeded in the three phases (i) Lie groups, symmetries and relativity; (ii) evolution equations and propagation of singularities; (iii) nonlinear models with stochastic processes from October 15 - December 20, 1997 (with an early contribution of P. Olver in September). The general and intended character of the project was to bring together experts from

these fields with a core of researchers in algebras of generalized functions for talks, discussions and joint research.

There were 30 invited visitors, 4 guests from abroad visited at their own expense, and 10 - 15 mathematicians and physicists from Vienna participated regularly in research and discussions.

Results. In the sequel, the activities and results will be grouped roughly according to the themes of the three phases, with an additional item: structure theory and interaction with quantum field theory. Following the description of activities, main results (which were obtained at the workshop and have led or will lead to publications) are emphasized separately.

Lie groups, symmetry and relativity. In this area, four topics were pursued:

(i) Lie group actions on generalized solutions to nonlinear partial differential equations. This involved nonlinear transformations of delta waves, invariance of solutions in the sense of association to hyperbolic systems of conservation laws under group transformations, nonprojectable group actions in algebras of generalized functions, and Lie semigroups (Dapic, Hermann, Kunzinger, Rosinger, M.O.). **Results:** it Sufficient conditions for invariance in the association sense, new examples of transformation of delta waves.

(ii) Ordinary differential equations and generalized functions. Study of ordinary differential equations in Colombeau algebras, control theory, and delta function terms (Hermann, Nedeljkov, Gramchev, M.O.). **Results:** it A class of ODEs with delta function terms was found which admits distributional solutions.

(iii) General relativity: Foundations were laid for modelling distributional curvature by means of generalized function algebras, and geodesics as well as symmetries in impulsive gravitational waves were studied (Vickers, Steinbauer, in collaboration with Aichelburg, Balasin). **Results:** it Computation of broken geodesics and geodesic deviation in the geometry of pp-waves.

(iv) First investigations into geometric theory of generalized functions on manifolds, and generalized manifolds (Hermann, Hazewinkel, Kunzinger, Kriegl).

Evolution equations and propagation of singularities. Activities in this area can be summarized in three groups:

(i) Schrödinger equations. The nonlinear Kronig-Penney model was investigated both in algebras of generalized functions and concerning distributional limits; and similarly the semilinear Schrödinger equation with additive white noise (Lange, Russo, M.O.). Further, operator theory methods were developed that apply to generalized function potentials in the linear, stationary Schrödinger equation (Antonevich, Radyno). **Results:** it Solution of the nonlinear Kronig-Penney model and limiting behavior for positive measures as potential; generalized solutions to the linear Schrödinger equation with additive white noise.

(ii) Hyperbolic conservation laws and related topics. The nature of singular shocks and delta shocks in conservation laws was clarified (Keyfitz, M.O.). All possible Rankine-Hugoniot conditions obtainable in solutions in the sense of association, using generalized Heaviside functions to solve the Riemann problem, were characterized (Egorov, M.O.). The relation of Colombeau solutions to Maslov asymptotic solutions was investigated (Omel'yanov). In models with dispersion or diffusion, blow-up mechanisms were studied (Bona, Scialom, Egorov). **Results:** it Discovery of the occurence of singular shocks in systems obtainable from gas dynamics; characterization of all possible Rankine-Hugoniot conditions.

(iii) Regularity theory. The notion of $\mathcal{G}^\infty$-regularity was further developed, in particular, $\mathcal{G}^\infty$-hypoellipticity of linear operators with non-constant, degenerate coefficients (Reissig) as well as linear operators with constant, generalized coefficients (Pilipović, Nedeljkov). Modelling of boundary layers in generalized functions was discussed (Gues). In diffusion equations, general results on the propagation region of analyticity and Gevrey regularity of initial data were obtained (Biagioni, Gramchev). **Results:** it $\mathcal{G}^\infty$-hypoellipticity of a class of degenerate operators was proved, determination of propagation domains of analyticity in Kuramoto-Sivashinsky-type equations.

In addition, the construction of Colombeau solutions in semilinear elliptic equations (Marti, Scarpalezos, Delcroix) and nonlinear Klein-Gordon equations (Pilipović, Nedeljkov, Wang, M.O.) was continued.

Nonlinear models with stochastic processes. The main investigations focused around semilinear heat equations with additive and multiplicative white noise, study of pathwise limits and asymptotic series in Wick renormalized solutions (Russo). This was extended to semilinear wave- and Schrödinger equations. Mechanisms leading to 'trivial' limits were further investigated. A comparison of the Colombeau approach and the Hida white noise approach to stochastic PDEs led to a unification on a higher level of generalization. The possibility of using the concept of viscosity solutions in the Hida white noise approach was discussed (Holden, Øksendal). Various notions of 'measurement solutions' (regularized derivatives) as related to stochastic differential equations and Colombeau generalized functions were discussed (Ubøe, Zhang). **Results:** *A general theorem on pathwise limits explaining the mechanism in semilinear stochastic PDEs with additive white noise was proven. The case of multiplicative white noise in the semilinear heat equation was settled.*

Structure theory, quantum field theory. Various approaches to the construction of Colombeau generalized functions (scales, seminorms, sheaf methods, nonstandard valuations) were unified (Marti, Radyno, Scarpalezos, T. Todorov). A first construction of a Colombeau-type algebra containing periodic hyperfunctions was obtained (Valmorin). A characterization of $\mathcal{G}^\infty$-regularity in terms of generalized point-values was achieved (Pilipović, M.O.). The applicability of infinite dimensional differential calculus to characterize Colombeau generalized functions was investigated (with Kriegl). **Results:** *Construction of Colombeau algebras containing periodic hyperfunctions, point-value characterization of $\mathcal{G}^\infty$-regularity.*

As a result of interaction with the ESI-program 'Local Quantum Physics' (organizers: D. Buchholz, J. Yngvason, H. Narnhofer), the question of applicability of generalized function algebras in renormalization problems of quantum field theory was repeatedly discussed with I. Todorov, H. Grosse, B. Kuckert and others. Certain regularization processes in the Thirring model were seen to be representable by Colombeau generalized functions.

Publications. Apart from the ESI-preprints listed separately, the volume **Nonlinear Theory of Generalized Functions** described below contains short review articles on the fields represented by the participants, in their interaction with the questions of nonlinearity and singularities as worked out during the program. It is intended as a survey of the state of the art in the field.

Further, a book project 'Geometric Theory of Generalized Functions', as a collaboration of M. Grosser, M. Kunzinger, M.O., R. Steinbauer was initiated as a result of discussions at the workshop. It has been accepted for future publication by Kluwer.

In addition, the work 'Parametric Lie Group Actions on Global Generalized Solutions of Nonlinear PDEs' presented by E.E. Rosinger at the workshop has also been accepted for publication by Kluwer.

Collaborations initiated. Apart from various collaborations among participants already existing, a number of new joint projects were started as a consequence of the workshop. This includes work on general relativity involving J. Vickers, R. Steinbauer, H. Balasin (Southampton - Vienna); a joint project on Lie transformation groups with S. Pilipović and his school and M. Kunzinger, M. Grosser (Novi Sad - Vienna); nonlinear Schrödinger equations with H. Lange and M. Oberguggenberger (Köln - Innsbruck) and fundamental solutions to linear PDEs in the Colombeau setting, N. Radyno and M. Oberguggenberger (Minsk - Innsbruck).

Conclusion. From my point of view, the project successfully achieved its aims. The nonlinear theory of generalized functions has found a firm place in mathematical analysis. New applications and extensions of old applications demonstrated its applicability in a wide range of problems. Apart from the mathematical benefits of the project, the interaction with local and invited physicists proved particularly fruitful. The project also served to crystallize new directions of research in nonlinear models with generalized functions. Notably, the main focus in the near future will be on differential geometric aspects, applications to general relativity, regularity theory in partial differential equations and structure theory of algebras of generalized functions.

I would like to add that all participants were highly satisfied with the working conditions and stimulating atmosphere at the Erwin Schrödinger Institute. I also pass on the enthusiastic words of praise for

institution and administration of the Erwin Schrödinger Institute that were expressed by practically all participants.

Proceedings. Proceedings of the workshop: Nonlinear Theory of Nonlinear Functions. Erwin Schrödinger Institute, Vienna, October – December 1997. Michael Grosser, Günther Hörmann, Michael Kunzinger, and Michael Oberguggenberger, (Editors). Chapman & Hall/CRC, Boca Raton, London, etc., 1999. 383 pages.

Contents

Workshops organized outside the main programs

Winter school in geometry and physics

January 11–18, 1997, Srní, Czech Republic, with a contribution by ESI of ATS 10.000. The proceedings were published in Suppl. Rend. Circ. Mat. Palermo, II. Ser. **54** (1998), 11–124.

Contents:

Conference on formal power series and algebraic combinatorics

The 9th conference in this series was organized by Christian Krattenthaler at the University of Vienna, July 14–18, 1997. ESI contributed ATS 50.000 to this conference. The proceedings are published as a special volume in 'Discrete Mathematics'.

Contents:

Visitors outside the main programs

ESI spent ATS 323.000, with external contributions amounting to ATS 723.000.

The following preprints were contributed: [431], [440], [443], [478], [490], [415], [419], [426], [435], [452], [453], [454], [465], [466], [479], [482], [485], [496], [506], [514], [523], [421], [447], [480], [481], [495], [500], [514], [527], [526], [450].

Thomas Hoffmann-Ostenhof as local coordinator of the EU TMR-network 96-0001 'Partial Differential Equations and Applications in Quantum Mechanics' (November 1996–October 2000), provided a total ATS 2,5 Mio. to be spent on visitors and post-docs at ESI during this period.

The year 1998

General remarks

Management of the Institute

Honorary President: Walter Thirring
President: Jakob Yngvason
Directors: Peter Michor and Klaus Schmidt
Administration: Lilla Hartyani, Ulrike Fischer, Ursula Sagmeister
Computers: Andreas Čap, Hermann Schichl

International Scientific Advisory Committee

Jean-Pierre Bourguignon (IHES)
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Alexander Kirillov (Pennsylvania)
Othmar Loos (Innsbruck)
Domokos Szasz (Budapest)

Budget and visitors: The budget of ESI for 1998 was ATS 10,5 Mio. (about €763.100). ATS 4,28 Mio. were spent on scientific activities and ATS 4,266 Mio. on administration and infrastructure. Visitors supported from other sources contributed the equivalent of a further ATS 2,3 Mio.

The number of scientists visiting the Erwin Schrödinger Institute in 1998 was 333, and the number of preprints produced was 133.

Programs in 1998

Spectral geometry and its applications

Organizers: L. Friedlander and V. Guillemin.

Total budget (including follow-up activities): ESI: ATS 886.000, external sources: ATS 16.000.

Dates: February – July, 1998.

Preprints contributed: [534], [539], [540], [542], [547], [548], [552], [567], [568], [569], [570], [572], [573], [574], [575], [577] [578], [583], [585], [600], [659], [673].

Report on the program by L. Friedlander

Several directions of the research in Spectral Geometry were represented in the program. There was a seminar running throughout the program, with the meetings on a weekly basis. In addition, there was an enormous amount of cooperation with the program on the Magnetic Schrödinger Operator that was taking place at the same time.

1) Robert Brooks, who was the first visitor, finished his paper on the Riemann surfaces with the big first eigenvalue. He constructed a family of surfaces of growing genus, the first eigenvalue of which has a uniform positive lower bound.

2) In March–early April, the main concentration was on the Spectral Geometry on singular spaces. Three visitors, Daniel Grieser, Matthias Lesch, and Olga Simek, were working in this area. They had numerous discussions, which were especially beneficial for Olga Simek, who has just got her PhD. Matthias Lesch finished his paper, in collaboration with Marcus Pflaum, on the traces on algebras of parameter dependent pseudodifferential operators.

Alexander Felshtin and Yuri Kordyukov visited the Institute at the same time. Alexander Felshtyn studies the Reidemeister torsion. He had lenthly discussions on the subject with Leonid Friedlander. While staying in the Institute, he finished the paper 'Reidemeister Torsion and Integrable Hamiltonian Systems'. Yuri Kordyukov was studying the Dirac Operator on the Riemannian foliations. He discussed the problems with Leonid Friedlander and Matthias Lesch.

3) In April–May, the major concentration was in scattering theory. Three leading experts in the field, Veselin Petkov, Georgi Vodev, and Maciej Zworski were in residence at that time. The major discussions were concentrated around the problem of the distribution of scattering poles. Maciej Zworski finished the paper on the Poisson formula for resonances in even dimensions, and, in this paper, he acknowledges the fruitful discussions with Georgi Vodev that took place in the Institute. Moreover, Vodev and Zworski started collaborating on a new project.

4) Michael van den Berg was working on the heat trace and the heat content for domain with singular boundary, and, in particular, he studied the case of the fractal boundary. There are many exciting problems in the field, and two talks that van den Berg gave resulted in lively discussions.

5) Dan Burghelea, Leonid Friedlander, and Thomas Kappeler have been collaborating for a number of years. They were discussing the problems related to the equivariant torsion, the determinants of elliptic operators in the case when the variables can be separated.

6) Steve Zelditch and Andrew Hassel were working on their project of relating the determinants to the scattering operator. They consider a bounded domain, and the problem is, how the determinant of the Laplacian in the domain is related to the scattering operator in the exterior. This problem is closely related to the Mayer–Vietoris type formula for the determinants that was established by Burgelea, Friedlander, and Kappeler. They discussed their problem with Friedlander. While in the Institute, Steve Zelditch also finished his paper, in collaboration with Bernard Shiffman, on the distribution of zeros of random and quantum chaotic sections of positive line bundles.

7) Dan Burghelea, Michael Farber, Daniele Guido, and Tomasso Isola had numerous discussions about the Novikov–Shubin invariants and related problems in Operator Algebras theory.

8) Leonid Friedlander and Nikolai Nadirashvili worked on the min-max properties of the first eigenvalue of the Laplacian. They considered the supremum of the first positive eigenvalue of the Laplacian over all metrics of volume 1 in a given conformal class, and then the infimum of these supremums over all conformal classes. They proved that the result is non-trivial (neither 0 nor infinity).

In general, the program provided an opportunity for people working in different aspects of Spectral Geometry to learn more about each other's work, to learn new ideas. Several new collaborations were started. Both well established and young mathematicians participated in the program.

Center of this program was the following workshop.

Workshop in Spectral Geometry and its Applications, Vienna, June 15–19, 1998

Program

Victor Guillemin, MIT, Paired Lagrangian distributions.
Eckhard Meinrenken, University of Toronto, Quantization commutes with reduction for loop groups.
David Borthwick, Emory University, Embedding symplectic manifolds via spectral theory.
Robert Brooks, Technion, Haifa, Riemann surfaces with large λ_1.
Chris Judge, University of Indiana, Large eigenvalues and short geodesics on hyperbolic surfaces.
Peter Perry, University of Kentucky, Isoscattering Schottky groups.
Jochen Brüning, Humboldt University, On boundary value problems for Dirac type operators.
Horst Knörrer, ETH, Zürich, Asymmetric Fermi surfaces for periodic magnetic Schrödinger operator.
Nicholas Ercolani, University of Arizona, An approach to eigenvalue statistics for coupled invariant random matrix ensembles.

Kate Okikiolu, UCSD, Critical metrics for the determinant of the Laplacian.
Michel Lapidus, UC Riverside, Complex dimensions of fractal strings and oscillatory phenomena, via Zeta-functions.
Michiel van den Berg, University of Bristol, Heat equations on the arithmetic van Koch snowflakes.
Thomas Kappeler, University of Zürich, KAM for KdV.
Evgeni Korotyaev, St. Petersburg, Geometry problems for the Hill operator.
Richard Melrose, MIT, Contact maps and the index of Fourier integral operators.
Thierry Paul, University Paris Dauphine, Perturbation of semiclassical limit.
John Lott, University of Michigan, Invariant currents on limit sets.
Gregory Eskin, UCLA, Inverse scattering problems in anisotropic media.
Mikhail Agranovich, Moscow Institute of Mathematics and Electronics, Spectral problems for the Helmholtz equation and the Lame system in Lipschitz domains, with the spectral parameter in boundary conditions.
Jared Wunsch, Harvard University, The trace of the harmonic oscillator.
Dan Burghelea, Ohio State University, Witten–Helffer-Sjöstrand theorems in the presence of symmetry.
Michael Farber, Tel Aviv University, Ray–Singer metric and torsion of Euler structures.
Peter Kuchment, Wichita State University, Geometry of photonic crystals and spectral geometry.
Matthias Lesch, Humbold University, The inverse spectral problem for Dirac systems on the half-line.
Andrew Hassell, Australian National University, The resolvent of scattering Laplacian.
Yoshi Maeda, Keio University, Groups of quantized volume preserving diffeomorphisms.
Steve Zelditch, Johns Hopkins University, Distribution of zeroes of chaotic and random eigenfunctions.
Zeev Rudnick, Tel Aviv University, Level spacing distributions for integrable systems.
Frederic Klopp, University Paris–Nord, Spectral problems in solid state physics.
Anders Melin, Lund Institute of Technology, Exceptional points and normal forms of Schrödinger operators.
Victor Ivrii, University of Toronto, Eigenvalue asymptotics for the neumann Laplacian in domains with ultra-thin cusps.

Schrödinger operators with magnetic fields

Organizers: I. Herbst, T. Hoffmann-Ostenhof and J. Yngvason.

Total budget (including follow-up activities): ESI: ATS 582.000, external sources: ATS 753.000 (mainly from an EU-project, which included one EU financed post-doc position).

Dates: March – June, 1998.

Preprints contributed: [527], [550], [559], [560], [562], [563], [564], [567], [568], [569], [571], [580], [582], [591], [597], [603], [604], [606], [607], [608], [643], [652], [657], [658], [665]. Korotyaev ([567], [568], [569]) was also invited to the program of spectral geometry, and Erdös in collaboration with Yau contributed a paper [657] which was also was also supported by the program on 'Kinetic theory'.

Report on the program by T. Hoffmann-Ostenhof

The topic of Schrödinger operators with magnetic field is a very active subject, both in mathematics and physics. One of the reasons is the fact that many properties of Schrödinger operators without magnetic field only partly carry over to the magnetic case, the mathematics and the underlying physical pictures are only poorly understood. For instance the ground state of a magnetic Schrödinger operator is not necessarily unique in contrast to the case without magnetic field.

Some of the topics and problems intensively discussed during the program were:

Scattering theory: Gerard, Herbst, Korotyaev, Laba, Skibsted ...

Periodic Schrödinger operators with magnetic fields: Birman, Cornean, Gruber, Hempel, Korotyaev, Macris, Shen, Sobolev, Suslina ...

Semiclassical problems (also Pauli operators): Erdoes, Fournais, Ivrii, Herbst, Laptev, Lewis, Nakamura, Weidl, Yngvason ...

General problem concerning eigenvalues and eigenfunctions: Birman, Hoever, Helffer, M. and T. Hoffmann-Ostenhof, Kurata, Laptev, Solovej, Laptev, Nenciu, Solovej, Weidl ...

Relativistic problems and quantum field problems: Bach, Balinsky, Evans, Bugliaro, Lieb, Loss, Ostergaard, Siedentop ...

Atomic problems: Balodis, Brummelhuis, Ivrii, Ruskai, Vugalter, Yngvason, Zhislin ...

These problems certainly overlap and the discussions also with the participants of the spectral geometry program led to new insights.

About one third of the participants were not supported by the ESI. In particular an EU program made it possible for some Post Docs to participate in the workshop.

The main concentration of the program was the following two-week conference.

Conference on Schrödinger operators with magnetic fields, 2.6. - 12.6.1998.

Program:

G. Nenciu: Magnetic Schrödinger operators: Perturbation theory and enhancement of eigenfunction decay.
H. Cornean: 2-dimensional magnetic Schrödinger operators: width of minibands in the tight binding approximation.
R. Zhdanov: On separation of variables in the Schrödinger equation for a particle interacting with external field.
R. Hempel: Periodic Schrödinger operators with magnetic perturbations and eigenvalues in gaps.
L. Bugliaro: Lieb-Thirring estimates and stability of matter coupled to QED.
Z. Shen: On moments of eigenvalues for the Pauli operator.
M. Griesemer: On instability of relativistic matter with self-generated magnetic field.
C. Gerard: An introduction to scattering theory of N-particle systems in magnetic fields.
I. Laba: Geometric methods in N-body scattering in magnetic fields.
E. Korotyaev: Scattering of three particles in a homogeneous time periodic magnetic field.
A. Sobolev: Absolute continuity of the magnetic Schrödinger operator.
E. Skibsted: Completeness for particles in combined constant electric and magnetic field.
G. Zhislin: Spectral properties of many-particle Hamiltonians with a homogeneous magnetic field with fixed pseudomomentum.
M. Gruber: Noncommutative Bloch theory and gauge-periodic magnetic Schrödinger operators.
R. Lewis: Eigenvalue estimates in the semiclassical limit for Pauli and Dirac operators with a magnetic field.
J. Solovej: Constructing zero eigenfunctions for magnetic Dirac operators on S^3 and $\mathbb{R}^3$.
A. Laptev: The negative discrete spectrum of a class of 2-dimensional Schrödinger operators with magnetic fields.
T. Suslina: 2-dimensional periodic Pauli operator. Effective masses at the lower point of the spectrum.
M. Birman: The periodic Schrödinger operator and Dirac operator. Sufficient conditions for the absolute continuity.
J.M. Combes: About spectral gaps for Maxwell equations in periodic dielectric media.
V. Bach: Stability of the groundstate and instability of excited levels for an atom minimally coupled to the quantized electro-magnetic field.
B. Helffer: Nodal sets for the groundstate of the Schrödinger operator with zero magnetic field in a non simply connected domain.
W. Evans: Stability of 1-electron molecules in the Brown-Ravenhall model I.
A. Balinsky: Stability of 1-electron molecules in the Brown-Ravenhall model II.
H. Siedentop: On the stability of the relativistic electron-positron field.
P. Balodis: On the asymptotic exactness of Thomas-Fermi Theory in the thermodynamical limit.
P. Kerdelhue: Resonances generated by a critical point of the potential.
G. Hoever: On the spectrum of a special magnetic Schrödinger operator.
N. Macris: Recent results on the localization length for Quantum Hall systems.
G. Raikov: Asymptotic properties of the magnetic integrated density of states.
K. Kurata: An estimate of the heat kernel of magnetic Schrödinger operators and uniformly elliptic operators with non negative potentials.
I. Herbst: Generalized Fourier transform for Schrödinger operators with potentials of order zero.
A. Suzko: Exact solutions for Schrödinger equations.
S. Fournais: Semiclassics of the quantum current in weak and strong magnetic fields.
B. Ruskai: A bound on the maximum negative ionisation of 1-dimensional models for many electron atoms in extremely strong magnetic fields.
R. Brummelhuis.
S. Nakamura: Tunnelling estimates for magnetic Schrödinger operators.
L. Erdös: Lifschitz tail in a magnetic field: the non classical regime.
T. Weidl: Virtual boundstates and Schrödinger type operators with magnetic fields.
T. Ostergaard: The relativistic Scott correction.
V. Ivrii: Atoms and molecules in the strong magnetic field.
J. Yngvason: Temperature dependent Thomas Fermi theory with a magnetic field.

Number theory and physics I. Convexity

Organizer: P.M. Gruber.

Total budget (including follow-up activities): ESI: ATS 298.000, external sources: ATS 25.000.

Dates: Fall 1998.

Preprint contributed: [637].

Report on the program

The participants N. Dolbilin (Moscow), R. Erdahl (Kingston/Ont.), M. Henk (Berlin), J. Martinet (Bordeaux), L. Michel (Paris), H.-G. Quebbemann (Oldenburg), S. Ryskov (Moscow), R. Scharlau (Dortmund), M. Senechal (Northampton, MA), B. Venkov (St. Petersburg), J. Wills (Siegen) worked on the following topics:

Dolbilin: Criterion for a convex polytope to be a cell of an isohedral tiling. A special case is the Venkov-Alexandrov-McMullen theorem on parallelohedra. Joint work with Michel, Senechal and Erdahl on parallelohedra. Article: 'The extension theorem'.

Erdahl: Investigation of perfect ellipsoids and their relations to lattice coverings and Delone tilings. Joint work with Senechal on zonotopes and with Senechal and Dolbilin on Voronoi's conjecture.

Henk: Algorithm for the determination of densest lattice packings of 3-polytopes. Special cases: dodecahedron, icosahedron, Archimedean solids. Article: 'Densest lattice packings of 3-polytopes' with U. Betke. Book: 'Finite and infinite packings' with J. Wills.

Martinet: Classification of integral lattices, continuing work of B. Venkov. Article: 'Sur certains designs spheriques lies a des reseaux entiers.'

Michel: Can one choose a basis of a lattice from the facet vectors of the corresponding Dirichlet-Voronoi cells? Discussions and joint work with Senechal, Dolbilin and Ryskov on lattice tilings and quadratic forms. Article: 'The invariance'

Quebbemann: Modularities of integer lattices and applications to theta functions. Joint work with Dolbilin, Erdahl, Scharlau and Venkov.

Ryskov: Investigation of Voronoi polytopes. Collaboration with Michel and Senechal on parallelohedra.

Senechal: Investigation of space filling zonotopes and lattice dicing with Erdahl. Problem, whether from the facet vectors of a Voronoi cell of a lattice one can choose a basis. Joint work with Michel and Ryskov. Book: Monograph on 'Lattice geometry' with Michel.

Wills: Articles: 'Densest packings of more than three d-spheres are non-planar' with U.Schnell. 'Quasicrystals, parametric density and Wulff shape' in 'Handbook of quasicrystals' with K. Boeroezcky, U. Schnell.

The participants appreciated the excellent atmosphere at the Schrödinger Institute which promoted discussions and joint work.

Number theory and physics II. Quantum field theory and the statistical distribution of prime numbers

Organizer: I. Todorov.

Total budget (including follow-up activities): ESI: ATS 552.000, external sources: ATS 347.000.

Dates: September – November, 1998.

Preprints contributed: [605], [609], [611], [617], [619], [620], [621], [623], [653], [673], [778], [805], [828], [975], [986].

Report on the program

There were 49 participants outside of Austria; 29 of them were supported (in part) by ESI.

The aim of the activity was to encourage contacts and interaction between mathematicians working on advanced topics centred around number theory and theoretical physicists interested in the applications of modern mathematical methods. It was the second major gathering of this type after the 1989 Les Houches meeting. One can single out several directions of activity which will be listed in, roughly, chronological order.

1. Victor Kac (who was at ESI through the month of September together with his graduate student B. Bakalov, supported in part by US funds) helped organize an activity on infinite dimensional (conformal, vertex operator, and supersymmetry) algebras. He reported his major work on the classification of simple infinite dimensional groups of supersymmetry which appeared as an ESI preprint with an addendum concerning a possible application to 'grand unified' models in particle physics triggered by discussions at ESI after his talk. Other high points on the mathematics side of this part of the program included a talk by Don Zagier modular forms and one by Terry Gannon on monstrous moonshine. Physical applications of conformal current algebras and $W_1 + \infty$ symmetry were centered around the fractional quantum Hall effect. A work (by Cappelli et al.) based on an earlier study of affine orbifolds (by Kac and Todorov at a 1996 ESI program) was completed during the workshop and appeared as an ESI report.

2. The central event of the entire program was the Conference on the Riemann Zeta Function (September 21-25) organized jointly with the American Institute of Mathematics (which covered the expenses of all 19 invited speakers during their entire — up to 12 days — stay at ESI). See below for the program. It was preceded by talks on the same subject by Michael Berry, Paula Cohen and Michel Lapidus during the first and the third week of September. A closely related development on the Hopf algebra structure of quantum field theoretic renormalization and the appearance of multiple zeta values in divergent integrals associated with Feynman graphs deserves mentioning: it involved joint work (and seminar talks) at ESI of David Broadhurst and Dirk Kreimer which started prior to the conference and the continuation of a collaboration between Connes and Kreimer which revealed a common (Hopf algebra) structure in renormalization theory and noncommutative geometry. A high point of the conference was the talk of its initiator and coorganizer Alain Connes 'Trace formula, absorption spectra and the zeros of the Riemann zeta function' based on his recent work which first appeared as an ESI preprint. The level of the entire meeting, marked by the presence of a grand master in the subject, Atle Selberg, can be hardly overstated.

3. A small scale activity that took place in mid November was helped by Boris Dubrovin (SISSA, Trieste) who not only gave a memorable talk on 'Reflection groups and Frobenius manifolds' but also attracted other participants. ESI support and the creative atmosphere at the Institute made possible a fruitful interaction between Klaus Wirthmueller (Kaiserslautern) and Dubrovin and his student M. Bertola on problems related to elliptic meromorphic structures and Jacobi forms. Discussions with participants of the part of the program organized by Peter Gruber during this period (in particular, with Boris Venkov) were very useful, too. Interactions with participants in other ESI programs appeared in previous months as well. Thus, Juergen Fuchs (who took part in the program on anomalies) presented a talk on 'Galois symmetries in conformal field theory' at the Number Theory and Physics workshop in October. Mixing between programs also led to a joint work started during a 1997 ESI program by H. Grosse (Vienna), M. Oberguggenberger (Innsbruck) and I. Todorov which was completed in November 1998 (and reflected in an ESI report).

Conference on the Riemann zeta-function, September 20 – 25, 1998.

Program:

S. Patterson: The Riemann zeta function and Hamburger's theorem.
D. Zagier: The Selberg zeta function, transfer operators, and periods of Maass wave forms.
C. Deninger: Motivic and dynamical cohomologies.
B. Julia: 'Physical' parameters in zeta functions.
J. Keating: Random matrix theory and some zeta-function moments.
S. Haran: The mysteries of the real prime.
A. Knauf: Number theory, dynamical systems and statistical mechanics.
Z. Rudnick: Poisson spacing statistics in number theory and mathematical physics.
B. Conrey: Mollifying the zeta-function.
H. Iwaniec: The cubic moment of central values of automorphic L-functions.
C. Soule: On zeros of automorphic L-functions.
Yu. I. Manin: Quantum computing and factorization of large integers.
A. Odlyzko: The 10^{21}-st zero of the Riemann zeta function.
D. Goldfeld: Integral operators and zeros of the zeta function.
E. Saias and M. Balazard: The Nyman-Beurling equivalent form for the Riemann hypothesis.
A. Connes: Trace formula, absorption spectra and the zeros of the Riemann zeta function.
D. Hejhal: On the zeros of linear combinations of Euler products.
P. Sarnak: Zeros of zeta functions and symmetry.
A. Selberg: Zeros of linear combinations of L-functions.

Proceedings of this conference are available both in printed and electronic form at ESI: the latter under

`http://www.esi.ac.at/activities/archive/zetaproc98.html`

Contents of the proceedings:

Quantization, generalized BRS cohomology, and anomalies

Organizers: R.A. Bertlmann, M. Kreuzer, W. Kummer, A. Rebhan, M. Schweda.

Total budget (including follow-up activities): ESI: ATS 853.000, external sources: ATS 171.000.

Dates: September 28 – December 31, 1998.

Preprints contributed: [625], [629], [638], [639], [644], [647], [651], [664], [682], [683], [698], [709], [733], [780], [787], [789], [871], [879], [883], [894], [951], [961], [968], [982]

Report on the program

The program was devoted to three deeply interrelated subjects of mathematical physics and phenomenology: quantization of field theory, generalized BRS cohomology and anomalies, and thermal quantum field theory. More than 70 experts in this area participated and worked together in this project for 3 months. The program was focused in an intensive 10 days workshop at the beginning where also scientists from the universities of Vienna and from abroad participated. This activity was followed by a program which included about 2 talks and/or discussion sessions per week in the months October, November, December.

Algebraic methods: 1. Algebraic renormalization. The presentation of the talk by F.Gieres on gauge fixing and BRS-quantization of local Lagrangian field theories initiated a collaboration with the Brazilian group (Piguet, Sorella).

L. Baulieu reported on topological field theories in higher space-time dimensions with encoded duality properties. As a consequence of this report the question of the existence of the topological linear vector symmetry will be discussed in collaboration with H. Ita, K. Landsteiner, T. Pisar, J. Rant and M. Schweda. It is planned to invite also L. Baulieu to join this collaboration.

S.P. Sorella presented some novel results concerning the unification of topological field models and ordinary gauge field models leading directly to two international collaborations where papers have been already submitted for publication: hep-th/9902154, hep-th/9812040.

The talk of O. Piguet initiated two international collaborations with the Vienna group (O.M. Del Cima, M. Schweda) and the Brazilian group (D.N.T. Franco, L.P. Colatto, O. Piguet) on superspace renormalization in 3-dimensions at space-time and IR-anomalies. Parts of these results appeared already in hep-th/9902084.

The talk on the conformal transformation properties of the supercurrent given by K. Sibold entailed fruitful discussions with P. van Nieuwenhuizen and A. Schwimmer. The information of some work in progress has led to an invitation to Stony Brook.

During the workshop A. Schwimmer collaborated intensely with M. Henneaux on extended superconformal algebra in 3d-gravity in the Chern-Simons realization. A corresponding paper is in preparation.

Algebraic methods. 2: Wess-Zumino terms and quantization of anomalous theories. L. Bonora finished during his presence at the workshop the paper on matrix string theory and its moduli space, (hep-th/9901093) which was an outcome of discussions with M. Asorey. Considerations on anomalies in theories with branes are not yet finished. L. Bonora acknowledged fruitful discussions with P. van Nieuwenhuizen and R. Stora.

Algebraic methods. 3: Batalin-Vilkovisky antifield quantization. In his talk F. Brandt reported on his results on the local BRS cohomology in supergravity theories. His methods are useful for a wide class of problems, including the Dirichlet string analysis that Joaquim Gomis reported on in his talk. The supersymmetric extension of the analysis of the D-string is the subject of an ongoing collaboration of F. Brandt with A. Kling and M. Kreuzer, which has been started during our program and is expected to result in an ESI preprint in the near future.

Glen Barnich appreciated the chance to interact with a number of long-term collaborators and also started a new collaboration with P.A. Grassi from the MPI in Munich. In addition, his discussions helped to complete his paper on a very interesting non-renormalization theorem in the antifield formalism, which appeared as ESI-preprint [625] and was published in JHEP 12 (1998).

Mark Henneaux completed his work on p-form gauge theories, which appeared as ESI-preprint [644].

G.A. Vilkovisky took the research program as an occasion to revisit a long-standing unsolved problem in the theory of the Batalin-Vilkovisky, that of quantizing the master equation in the most general gauge. The solution was the topic of intense discussions, in particular with A. Rebhan, and is now published as ESI preprint [664]. The new ideas developed in this case could turn out to be fruitful in other examples of infinitely reducible gauge theories such as the covariantly quantized Green-Schwarz superparticle and superstring.

Geometric methods. 1. Topological and geometric aspects of anomalies. R. Stora found a link between the covariant anomaly (or chiral Bose-Einstein anomaly) of quantum field theory and the local form of the family's index theorem of Bismut. He also presented his view on Cheeger-Simons differential characters and the Beilinson-Deligne cohomology. Furthermore he was engaged in clarifying the work of T. Hurth and M. Skenderis on the quantum Noether method and in discussing specific problems of branes with L. Bonora and R. Minasian.

M. Asorey analyzed the topology of gauge orbit space, specifically, the features of a fundamental domain, of Gribov copies and of a Gribov horizon. This work has appeared already as ESI preprint [651]. His discussions on problems like global gauge fixing, integrable systems and matrix string models with other participants, notably with L. Bonora, initiated further work on this subject.

The theory of bundle gerbes applied to quantum field theory has been the research topic of J. Mickelsson. He showed how the Atiyah-Patodi-Singer index theory construction of the fermionic Fock space bundle leads to the known Schwinger terms, the Faddeev-Mickelsson cocycles, for the gauge group action. He also acknowledged the many discussions with R. Stora and R.A. Bertlmann on the possible inclusion of gravitation. These results will soon appear as an ESI preprint.

The subject of Schwinger terms (or anomalous commutators) has been addressed also by L. Faddeev. He presented a functional integral method for calculating the anomalous commutators of Gauss law operators in the theory of interacting chiral fermions with Yang-Mills fields.

In another project L. Faddeev and A.J. Niemi investigated the partial duality in SU(N) Yang-Mills theory. Their presentation in discussions with W. Kummer has resulted in an improved understanding of the soliton aspects of their approach. Their work has appeared already as ESI preprint [656].

The presentation of A. Vinogradov of his theory of secondary calculus found considerable interest, especially among the experts of BRS cohomology in QFT. The discussions with C. Becchi, R. Stora and M. Henneaux led to a better understanding of this field. The participation of J. Krasil'shchik with his contribution on SUSY and integrability resulted in ESI preprint [639], and the contributions of A. Verbovetsky on computing the horizontal cohomology will appear as a paper soon. Specific model calculations of the several types of anomalies have been performed by C. Adam, J.M. Pawlowski, J. Horejsi and M. Schnabl. The discussions with R.A. Bertlmann on a possible inclusion of gravitation into the approach of dispersion relations led to a joint project.

Mario Tonin of Padua reported on his new method to find invariant actions for chiral bosons and the relation to gravitational anomalies. This method is of great importance for the most recent research on branes and, therefore, was the subject of much clarifying discussions.

The new results of P. Grassi on renormalization with non-semisimple gauge theories close an old gap in the theory of renormalization.

D. Vassilevich together with W. Kummer wrote a paper which appeared already as ESI preprint [629]. It clarifies the relation of the four-dimensional scaling anomaly from scalars in Einstein gravity with one in the spherically reduced 2d case. In this manner the first calculation of Hawking flux without using the effective action approach was possible, avoiding uncertainties related to the latter approach. D. Vassilevich is also about to finish a paper with P. Gilkey who was a guest of ESI at the time of the workshop in another program.

Geometric methods. 2. Anomalies in strings and supersymmetry. K. Skenderis and T. Petkou as a consequence of their talks initiated a project with M. Henneaux and T. Hurth on counterterms in gauge fixed gauge theories which is expected to lead to a future publication.

A. Van Proeyen with J. Gomis as result of discussions on BPS-states intend to start a collaboration. A.Van Proeyen also appreciated the chance to have discussions with several leading experts (J. Gomis, R. Stora, M. Henneaux) for his ongoing research on N=2 supergravity.

The paper being prepared to write now on topological strings, contact terms and the holomorphic anomaly by C. Becchi and collaborators will be the consequence of the talk of Becchi at the workshop.

A number of interesting new types of anomalies came under considerations with the progress in non-perturbative string theory, where quantum field theories on solitonic objects (branes) of various dimensions and on boundaries thereof combine with the contributions of 'elementary' degrees of freedom in a generalized Green-Schwarz cancellation mechanism. These issues were discussed in the talks by Ruben Minasian and by Loriano Bonora, and were the subject of many discussions including also Jürgen Fuchs, Christoph Schweigert and Bert Schellekens, who is a specialist in the role of the elliptic genus in anomaly cancellation. Progress in the understanding of boundary conditions in exactly solvable conformal field theories resulted in the ESI-preprint [638]. A proper understanding of the relation between anomalies and tadpole cancellation, however, is still a challenging open problem. Schweigert and Minasian also considered anomaly cancellation and the role of K-theory for the M-theory five-brane.

Another collaboration that was initiated by the ESI program is the construction and cohomological analysis of toric complete intersections by David Sahakian and M.Kreuzer. These varieties are an important ingredient of realistic string models, which need to be based on a complicated balance among perturbative and non-perturbative contributions if the unification of all fundamental interactions is required to produce a reasonable value for the gravitational constant. The results will be published as an ESI preprint.

Among the guests who contributed most to the lively discussions was especially Peter van Nieuwenhuizen. He wrote after the conference that 'almost all the active people in the field were present' and praised the organizers for leaving enough time between the talks for further detailed discussions. In his talk he reported on new results on anomalies in strings, which was of high interest and stimulated further investigations in this field.

Anomalies at finite temperature. 1. Algebraic aspects. A thorough overview of algebraic aspects of thermal quantum field theories was given by C. Jaekel, in extension of earlier work that has already appeared as an ESI preprint. J. Yngvason presented new work on modular groups of quantum fields in thermal states, which also is the subject of an existing ESI preprint, initiating interesting discussions with ramifications that include effects like Unruh and Hawking temperature.

W. Thirring presented a historical overview of the Thirring Model with special emphasis of recent developments that are of particular relevance in thermal QFT.

On the formalistic side, there was also agitated discussion about a proposal by C. Lucchesi on implementing a superspace formulation, reviewed in generality by S. Joglekar, also in a thermal context. This approach aims at preserving the advantages of a superspace formulation at finite temperature, where the different statistics of Bose and Fermi particles ordinarily spoils supersymmetry.

Anomalies at finite temperature. 2. Phenomenological aspects. R. Baier, F. Gelis and M. Tytgat discussed the technical details of the chiral anomaly at finite temperature, their phenomenological implications, and a resolution of some recent controversy. This was met with considerable interest from theorists with profound phenomenological background such as H. Leutwyler, as well as from more 'theoretical' theorists, notably P. van Nieuwenhuizen, who greatly contributed to the synthesis achieved in these discussions. D. Miller reported on nonperturbative aspects of anomalies in QCD at finite temperature, in particular of the role of a gluon condensate on the trace anomaly, which will be elaborated further in a forthcoming ESI preprint. The connection of the trace anomaly with the thermodynamic pressure of QCD is also the central theme of a collaboration initiated later in the research program by P. Landshoff and A. Rebhan, with an ESI preprint currently in preparation. This new approach might have the potential to establish a novel nonperturbative basis for practical calculations of the QCD pressure, where conventional thermal perturbation theories have run into seemingly insuperable problems. A. Petkou with M. Silva Neto contributed a closely related work, already published as ESI preprint [647], which ties thermodynamic quantities, phase transitions, and scaling behaviour to formal properties of three-dimensional conformal field theory, making use of hitherto unexploited polylogarithmic identities. The ensuing discussions benefited among others by I.T. Todorov, who was present as participant of a different ESI research program.

Supplementary information on the research program including transparencies of talks can be obtained from our homepage: `http://tph16.tuwien.ac.at/ano98.html`.

Workshop on quantization, generalized BRS cohomology, and anomalies, September 28 - October 7, 1998.

Program:

R. Stora (Annecy): Two mathematical constructions related to anomalies.
L. Bonora (Trieste): M-theory anomalies (hep-th/9712205).
F. Gieres (Lyon): Gauge fixing and BRS quantization of local Lagrangian field theories.
G. Barnich (Brussels): A cohomological approach to the quantum Batalin-Vilkovisky formalism.
L. Baulieu (Paris): Batalin-Vilkovisky ghost unification and Seiberg-Witten duality.
F. Brandt (Hannover): (Extended) BRST cohomology in super-symmetric theories.
M. Tonin (Padova): Covariant actions for chiral bosons and gravitational anomalies.
P. van Nieuwenhuizen (Stony Brook): New anomalies in strings?
M. Asorey (Zaragoza): Gribov horizon and cohomology of orbit spaces.
C. Becchi (Genova): The BRS cohomology in topological sigma models.
O. Piguet (Victoria): Nonrenormalization theorems for 3-d gauge theories with topological terms.
S. Sorella (Rio de Janeiro): Remarks on Chern-Simons field theories.
S. Wolf (Geneva): The supercurrent trace identities of the N=1 D=4 SYM theory in the Wess-Zumino gauge.
V. Aldaya (Andalucia): Group approach to quantization, anomalies, constraints, and dynamical symmetry breaking.
A. Vinogradov (Salerno): Elements of secondary calculus and some expectations.
L. Vilar (Rio de Janeiro): A no-go theorem for the nonabelian topological mass mechanism in four dimensions.
M. Henneaux (Brussels): Consistent interactions between exterior form gauge fields: the BRST approach.
W. Thirring (Vienna): The Thirring model 40 years later.
C. Jaekel (Roma): Algebraic aspects of thermal quantum field theories.
J. Yngvason (Vienna): Modular groups of quantum fields in thermal states.
D. Miller (Hazleton): Anomalous currents and gluon condensates in QCD at finite temperature.
S. Joglekar (Kampur): Superspace formulation of gauge theories.
P. Grassi (Munich): Renormalization of non-semisimple gauge.
R. Baier (Bielefeld): Anomalous processes at high temperature.
F. Gelis (Annecy): Ambiguities in the zero-momentum limit of the thermal triangle diagram.
M. Tytgat (Brussels): Chiral dynamics and anomalous amplitudes at finite temperature.
J. Gomis (Barcelona): D-branes and BRST cohomology.
R. Minasian (New Haven): Anomalies for nonabelian tensor multiplets.
C. Schweigert (CERN): Boundary conditions for open strings and tadpole cancellation.
C. Lucchesi (Neuchatel): Thermal supersymmetry in thermal superspace.
A. Schwimmer (Rehovot): Aspects of 3-d gravity with extended supersymmetry in the CSW formulation.
T. Hurth (Munich): Quantum Noether method.
K. Sibold (Leipzig): The conformal transformation properties of the supercurrent.
I. Krasil'shchik (Moscow): Supersymmetry and integrability.
A. Verbovetsky (Moscow): On computing the horizontal (characteristic) cohomology.
H. Grosse (Vienna): Noncommutative manifolds as a regularization preserving symmetries.
J. Mickelsson (Stockholm): From euclidean Dirac determinants to hamiltonian anomalies.

J. Pawlowski (Dublin): On consistent and covariant anomalies in chiral gauge theories.
C. Adam (Dublin): Consistent and covariant commutator anomalies in the chiral Schwinger model.
J. Horejsi (Prague): Dispersive approach to anomalies.
M. Schnabl (Prague): Some aspects of the trace anomaly.

Continuation in 1999. The activity started end of June with the visits of R. Banerjee and T. Sykora who investigated the Hamilton approach to gauge theories. R. Banerjee presented a method for finding the complete set of gauge transformations for a given Lagrangian and T. Sykora could solve due to the fruitful discussions with R. Banerjee and H. Grosse a calculation of Schwinger terms in a 1+1 dimensional fully quantized theory. It appeared as ESI preprint No. 787. The output of the visit of L. Colatto are two preprints: 'Renormalization of N=1 super-QED3 coupled to parity-preserving matter' and 'No parity anomaly in massless QED3'. These works were done in collaboration with L.P. Colatto, O.M. Del Cima, D.H.T. Franco, O. Piguet and M. Schweda. S. Krivonos has been invited as a specialist on partial breaking of global supersymmetry in connection with the supermembrane. The invitation of D. Sorokin was a consequence of his extensive work on superconformal theories and supertwistor dynamics. In December there was an activity on the geometric aspects of quantum field theory. C. Ekstrand gave a talk on the joint work with J. Mickelsson (who participated in the anomaly' program last year) explaining the theory of bundle gerbes applied to the calculation of anomalies and Schwinger terms (inclusive gravitation), the work appeared as ESI preprint No.698. C. Adam (who also participated last year) reported on his recent successful efforts (together with C. Nash) to relate the zero-modes of the Dirac operator (in 3 dimensions) to Hopf maps. The discussion of the open problems in this connection led to a joint collaboration of Adam, Ekstrand, Sykora and Bertlmann. The program ended with a visit of P. Landshoff, originally scheduled for December but slightly postponed for beginning of January, which was devoted to a continuation of work on consequences of the trace anomaly in thermal quantum field theory. This work was begun in the previous year within the research program and first results were published as ESI preprint 709 (by now published in Physics Letters B) together with A. Rebhan. It also should be mentioned that several discussions benefited much by L. Faddeev, I.T. Todorov and H. Grosse, who were present as participants of an other ESI research program.

Supplementary information on the research program including transparencies of talks can be obtained from our homepage: `http://tph16.tuwien.ac.at/ano98.html`.

Charged particle kinetics

Organizers: C. Schmeiser and P. Markowich.

Total budget (including follow-up activities): ESI: ATS 605.000, external sources: ATS 806.000.

Dates: October 5 - January 31, 1999.

Preprints contributed: [631], [633], [634], [646], [648], [655], [657], [661], [662], [667], [677], [678], [701], [702], [703], [704], [705], [706], [707], [728], [729], [738], [752], [777], [819], [833], [833], [859].

Report on the program

The program started with a workshop on ANALYTICAL TECHNIQUES AND ASYMPTOTIC METHODS FOR KINETIC EQUATIONS (Oct. 5 – 8, 1998), cosponsered by the EC-funded TMR Network on ASYMPTOTIC METHODS IN KINETIC EQUATIONS and by the ESI. The first day of the meeting was filled by invited one-hour presentations of leading scientists in the field. Carlo Cernignani (Milano) discussed new results in renormalized solutions of the Boltzmann equation, Giuseppe Toscani (Pavia) talked about the use of convex Sobolev-inequalities in the analysis of long time behaviour of nonlinear diffusion processes (e.g. porous media and fast diffusion flow), Patrick Gerard (Orsay) lectured about semiclassical limits in the presence of energy band degeneracies and Pierre Degond (Toulouse) presented asymptotic techniques for superlattice semi- conductor models. The remaining 3 days of the meeting were devoted to 1/2 hour talks on more specialized new developments in the field and to discussions on the strategic future of kinetic theory. In particular, there was total agreement that the derivation of single particle kinetic models from multi-particle dynamics is to be considered as one of the most significant

future challenges in the field (mathematical understanding of the onset of irreversibility, dissipation....). Another highlight of the meeting was the second presentation of Carlo Cercignani, which focused on the life and scientific work of Ludwig Boltzmann. This talk was extremely well received not only by invitees of the ESI-program, but also by mathematics and physics faculty of the University of Vienna due to its historic perspective. The total number of participants of the first meeting was about 40.

Thereafter the program continued in the form of short term visits (1-2 weeks) of main researchers in the field. Beyond that there were five long term participants:

Pierre-Emmanuel Jabin (Predoc from ENS Paris, ESI financed, October – December 1998),

Florian Frommlet (Predoc from TU-Berlin, TMR financed, October 1998 – March 1999),

Christian Ringhofer (ASU, September 1998 – Februar 1999, partially ESI financed),

Paola Pietra (Univ. Pavia, September 1998 – Februar 1999, partially ESI financed),

Francois Castella (CNRS Rennes, October 1998 – Februar 1999, TMR - ESI financed).

Jabin worked mainly on granular flow problems (with Pietra and Perthame), Frommlet and Castella interacted with Markowich and Ringhofer on the derivation of Lindblad models in Fokker-Planck form for electron- phonon interaction and Pietra also analyzed numerical methods for dispersive equations (with Markowich).

The second meeting of the program (again cosponsored by the TMR network on kinetic theory), on QUANTUM TRANSPORT MODELS AND DISPERSIVE EQUATIONS, took place at the ESI from January 11 – 13, 1999. As in the first meeting, the first day was again devoted to one-hour overview talks of very senior experts. The first lecturer was Claude Bardos (ENS Cachan) discussing scaling limits of kinetic systems. He was followed by David Levermore (Tucson) lecturing on the derivation of fluid dynamics from the Boltzmann equation, by Peter Deuflhard (Berlin) discussing computational quantum chemistry, by Benoit Perthame (ENS Paris) presenting an exciting new methodology to obtain (dispersion) estimates for the Helmholtz equation by means of Wigner transforms, and by David Mclaughlin (New York), who focused on the dispersive limit of nonlinear Schroedinger equations. The second day of the meeting was started by H.T.Yau (New York) presenting new work on the derivation of the elastic-scattering Boltzmann equation from the Schroedinger equation with a random potential (joint work with L. Erdoes, who also participated in the ESI program). Yau's talk was followed by 1/2 hour lectures mainly on integrable dispersive equations and local results for nonintegrable systems. A main result' of the meeting was the need to go beyond the existing (and already aging) theory of dispersive limits of totally integrable equations initiated by P. Lax and D. Levermore in the early 80' and to start to tackle nonintegrable highly nonlinear dispersive problems. It seems that the by now well-developed theory of Wigner transforms and Wigner measures is an ideal tool for this task, but it will take another quantum leap.

Important scientific interactions happened in January 1999. Of great significance for the program is the work on quasineutral limits for drift-diffusion systems (Gasser, Levermore, Markowich, Schmeiser), on discrete dispersive problems (Bertoluzza, Pietra), on the derivation of mean field quantum equations with singular interactions (Bardos, Markowich, Mauser, Yau), on analytical properties of quantum Fokker Planck systems (Arnold, Lopez, Markowich, Soler) and on convex Sobolev inequalities for nonlinear diffusion equations (Carrillo, Juengel, Markowich, Toscani).

Continuation of of the program in the year 2000. The following scientists were invited: Anton Arnold, Claude Bardos, Poitr Biler, Yann Brenier, Carlo Cercignani, Patricio Felmer, Francois Golse, Alex Gottlieb, Myo Theim Gyi, Hailiang Li, Emmanuel Jabin, Enrique Lami Dozo, Horst Lange, Claude LeBris, Claudia Lederman, Nader Masmoudi, Tadeusz Nadzieja, Nuykhat Nurlybayev, Shi Jin, Dmitri Petrina, René Pinnau, Mukhaya Rasulova, Gerhard Rein, José Francisco Rodrigues, Wilhelm Schlag, Maria Schonbek, Aleksandr Sinitsyn, Marin Soljacic, Giuseppe Toscani, Andreas Unterreiter, Shu Wang, Gershon Wolansky, Kaijun Zhang, Ping Zhang, Jorge Passamani Zubelli.

Workshops organized outside the main programs

Winter school in geometry and physics

January 10–17, 1998, Srní, Czech Republic, with a contribution of ATS 10.000 from ESI. The proceedings were published in Suppl. Rend. Circ. Mat. Palermo, II. Ser. **59** (1999), 7–228.

Contents:

Conference on epistemological and experimental perspectives on quantum physics

September 3-6, 1998. This conference was organized jointly with the 'Institut Wiener Kreis'. ESI contributed ATS 32.000 to this conference.

Program:

Abner Shimony (Boston University): Philosophical & Experimental Perspectives on Quantum Physics. '6th Vienna Circle-Lecture'.
Anton Zeilinger (Innsbruck/Vienna): Quantum Superposition and Information.
Jean-Marc Lévy-Leblond (Nice): Quantum Words for a Quantum World?
Don Howard (Notre Dame, IN): A Brief on Behalf of Niels Bohr.
Catherine Chevalley (Tours): On the Difference between Bohr's Epistemology and the so-called Copenhagen Interpretation of Quantum Theory.
Kurt Gottfried (Ithaka, NY): My Ongoing Debate with John Bell.
GianCarlo Ghirardi (Trieste): The Dynamical Reduction Program: An Example of a Quantum Theory without Observers.
Basil Hiley (London): The Bohm Interpretation, Active Information and Teleportation.
Roland Omnés (Paris): Decoherence and Irreversibility.
Wojciech Zurek (Los Alamos,NM): Decoherence, Einselection and the Existential Interpretation.
Walter Thirring (Vienna): Macroscopic Purification of States by Interactions.
Rainer Blatt (Innsbruck): Quantum Optics with Single Atoms.
Serge Haroche (Paris): Quantum Engineering with Atoms and Photons in a Cavity.
Harry J. Kimble (Pasadena, CA): The Cavity QED Circus - Flying Photons, Juggling Atoms, and Fantastic Finesse.
Peter Zoller (Innsbruck): Quantum Repeaters for Communication.
Helmut Rauch (Wien): Quantum Physics at Work.
Michael Horne (North Easton, MA): Complementarity of Fringe Visibilities in Three-Particle Quantum Mechanics.
Yuri Orlov (Ithaka, NY): Quantum and classical Gödelian Indeterminism, Measurement, and Informational Collapse into the Past.
Jakob Yngvason (Vienna): Causality Concepts in Local Quantum Physics.
Dik Bouwmeester (Innsbruck): Quantum Teleportation and Entanglement Swapping.

Erhard Oeser (Vienna): Epistemological Problems of Measurement of Quantum Mechanics and the Appearance of the Classical World of Macroscopic Objects.
Charles H. Bennett (New York): Classical, Quantum and Thermodynamic Resources involved in Quantum State Transformations.

Conference on the classification of filtrations of stochastic processes

November 30 – December 4, 1998, Erwin Schroedinger Institute, Vienna, Austria. The organizers were Walter Schachermayer and Klaus Schmidt. ESI contributed ATS 25.500, Walter Schachermayer contributed ATS 38.800.

Program:

A. Vershik: Theory of families of measurable partitions as geometric measure theory.
B. Tsirelson: The five noises.
M. Emery: Pure martingales and the chaotic representation property – is there a link?
J. Kallsen: A stochastic differential equation with a unique — up to indistinguishability — but not strong solution.
B. de Meyer: A simplification of Tsirelson's argument on the non-Brownian feature of the Walsh process.
M. Smorodinsky/J. Feldman: Sufficient conditions for a reverse filtration to admit a standard extension.
J. Warren: The noise made by the Poisson snake.
V. Kaimanovich: Tail sigma-algebras of Markov processes.
W. Schachermayer: Brownian filtrations are not stable under equivalent time changes.
M. Yor: On certain subfiltrations of the Brownian filtration.
M. Malric: Spider-martingales in the filtration of Walsh's Brownian motion.
J.-P. Thouvenot: How to get rid of decreasing sequences of σ-algebras.

Visitors outside the main programs

ESI spent ATS 861.000, with external contributions amounting to ATS 738.500.

Preprints contributed: [536], [553], [587], [626], [635], [538], [541], [551], [555], [557], [589], [642], [643], [650], [530], [544], [592], [593], [594], [595], [596], [598], [599], [601], [602], [610], [612], [618], [640], [645], [654], [660], [545], [576], [579], [581], [584], [586], [614], [615], [616], [628], [630], [632], [636], [641], [649], [663], [668], [669], [670], [672], [537], [546], [554], [556], [561], [588], [653], [549], [613].

The year 1999

General remarks

Management of the Institute

Honorary President: Walter Thirring
President: Jakob Yngvason
Directors: Peter Michor and Klaus Schmidt
Administration: Ulrike Fischer, Doris Garscha, Ursula Sagmeister
Computers: Andreas Čap, Gerald Teschl, Hermann Schichl

International Scientific Advisory Committee

Jean-Pierre Bourguignon (IHES)
Giovanni Gallavotti (Rome)
Krzysztof Gawedzki (IHES)
Harald Grosse (Vienna)
Vaughan Jones (Berkeley)
Victor Kac (MIT)
Elliott Lieb (Princeton)
Harald Niederreiter (Vienna)

Budget and visitors: The budget of ESI for 1999 was ATS 10,74 Mio. (about €780.500). About ATS 5 Mio. were spent on scientific activities and ATS 4,27 Mio. on administration and infrastructure. Visitors supported from other sources contributed the equivalent of a further ATS 2,15 Mio.

The number of scientists visiting the Erwin Schrödinger Institute in 1999 was 409, and the number of preprints produced was 168.

Programs in 1999

Functional analysis

Organizers: J. Cooper.

Total budget (including follow-up activities): ESI: ATS 1,02 Mio., external sources: ATS 770.500.

Dates: January – July, 1999.

Preprints contributed: [585] (1998), [671], [686], [687], [688], [689], [690], [691], [693], [694], [699], [700], [710], [711], [712], [713], [714], [718], [719], [721], [723], [724], [725], [726], [727], [732], [736], [746], [753], [772], [818], [823], [826], [845], [823], [826], [845], [849], [862], [860], [861], [866], [952], [1005], [1007], [1008], [1012], [1013], [1014], [1020], [1031], [1060].

Report on the program

The Functional Analysis Group of the Mathematical Department at the Johannes Kepler University organized a research semester at the ESI on the topics: operator algebras, convexity, complex function theory (with emphasis on the functional analytic aspects).

The idea of the research semesters at the ESI was to provide a forum for senior researchers and young mathematicians to interact, continue existing scientific projects or instigate new ones. In the case of the above semester this was enhanced by three international colloquia in Upper Austria.

As explicit examples of concrete research projects which were instigated or continued in Vienna we mention

- David Preiss, University College of London, Joram Lindenstrauss, Hebrew University of Jerusalem, Eva Matoušková, Czech Academy of Sciences, (Differentiation in Banach spaces)
- Carsten Schütt, Christian-Albrechts-Universität Kiel, Elisabeth Werner, Case Western Reserve University, Shlomo Reisner, University of Haifa, (Volume estimates for convex bodies)
- Peter Jones, Yale University, Paul Müller, Johannes Kepler Universität Linz, (Estimates for harmonic measure). (Preprints [732], [724], [725]).

The participants in the semester were leading researchers in analysis whose work has had a decisive influence on the development of their subjects. This is documented by the following facts:

A total of 111 mathematicians from the following countries took part; Austria, Germany, Swiss, France, Great Britain, Ireland, Denmark, Sweden, Norway, Italy, Spain, Greek, Russia, Poland, Czech Republic, Slovakia, Hungary, Japan, USA, Canada, Israel and India.

The following participants are holders of the prestigious Salem prize: C. Thiele, G. David, P. Jones, N. Makarov, S. Treil, A. Volberg, G. Pisier. Pisier is also holder of the Ostrowksi prize.

The following participants have held main talks at the International Mathematical Congresses:

Invited plenary talks:

A. Pełczyński 82, D. Voiculescu 94, G. Pisier 98,

Invited section talks:

J. Lindenstrauss 70, V. Milman 86, 98, N. Tomczak Jaegerman 98, Th. Schlumprecht 94, G. David 86, V. Havin 78, P. Jones 82, N. Makarov 86, A. Olevskii 86, G. Pisier 82, A. Pełczyński 66, D. Voiculescu 82, A. Volberg 90, D. Preiss 90, R. Longo 94.

The research semester was supported financially from the budget of the Schrödinger institute. This was used to finance the living costs of most of the foreign participants. Further financial support was provided by the International Mathematical Union, the Austrian Mathematical Union, the Government of Upper Austria, the City Council of Linz, the Linzer Hochschulfonds, VOEST-ALPINE Industrieanlagenbau GmbH and the Johannes Kepler University of Linz.

This covered the costs of the three international colloquia listed below and the organizers' living costs in Vienna.

In would like to conclude this report by expressing my gratitude to the above-mentioned sponsors and to my colleagues Renata Mühlbachler, Paul F.X. Müller, Michael Schmuckenschläger und Charles Stegall for their efforts which were indispensable for the success of this semester.

International colloquium on operator algebras. February 12 - 14, 1999, Landschloß Ort bei Gmunden.

Program:

Walter Thirring (ESI Wien): The Thirring Model 40 Years after.
Heide Narnhofer (Universität Wien): Anosov Property and K Property in quantum Systems.
Christian Jäkel (Universität Wien): Applications of modular theory in local quantum physics.
Ken Dykema (Odense Universitet): Exactness of reduced free product C^*-algebras.
Alexandru Nica (University of Waterloo): R-diagonal elements and freeness with amalgamation.
Flemming Larsen (Odense University): On powers of R-diagonal elements.
Daniele Guido (Universita della Basilicata, Potenza): Non commutative Riemann integration and singular traces for C^*-algebras.

Martin Mathieu (The Queen's University of Belfast): Automatic Continuity of Lie Homomorphisms on C^*-Algebras.
Anna Paolucci (University of Leeds): Duality for quantum groups and the Cuntz Algebra.
Ilona Krolak (Wroclaw University): Wick product for general commutation relations.
Romuald Lenczewski (Wroclaw University): The hierarchy of freeness - the GNS construction, limit theorems and other developments.
Piotr Sniady (Wroclaw University): Quantum Stochastic Calculus of Bounded Operators.
Wolfgang Lusky (Universität Paderborn): Fourier analysis of operators on Hilbert spaces of holomorphic functions.

International colloquium on convexity. April 9 - 11, 1999, Schloß Weinberg, Kefermarkt.

Program:

Joram Lindenstrauss (Hebrew University of Jerusalem): A new look at James's theorem.
Gilbert Helmberg (Universität Innsbruck): The speed of convergence for alternating series with a convexity property.
Christian Richter (Universität Jena): Linear combinations of partitions of unity with restricted supports.
Eva Matouskova (Czech Academy of Sciences): Lipschitz image of a null set can have null complement.
Thomas Schlumprecht (Texas A&M University)
Thomas Kühn (Universität Leipzig): The complex binary trilinear unit ball.
William B. Johnson (Texas A&M University)
Katalin Marton (Hungarian Academy of Sciences): Measure concentration for processes with memory.
Denes Petz (Technical University of Budapest): Monotone inner products on matrix spaces.
Frank Barthe (Universite de Marne-la-Vallee): A short solution of the Busemann-Petty problem.
Apostolos A. Giannopoulos (University of Crete): Isomorphic positions of convex bodies.
Yehoram Gordon (Technion): On volume ratios.
Gideon Schechtman (Weizmann Institute of Science): Lewis' change of density revisited.

International colloquium on complex function theory and functional analysis. June 3 - 5, 1999, St. Wolfgang am Wolfgangsee.

Program:

James Groves (University of Lancaster): Spectral representations of Banach space valued Ornstein-Uhlenbeck processes.
Silke Holtmanns (Universität Paderborn): Operator Representation for Weighted Spaces of Holomorphic Functions.
Peter W. Jones (Yale University): Continua support measures with bounded Cauchy Transforms.
Michael Kaltenbäck (TU Wien): Pontryagin Spaces of Entire Functions.
Bernd Kirchheim (Max Planck Institut Leipzig): Gradients without Rank-One Connections.
Heinz König (Universität des Saarlandes): Extension of the Riesz Representation Theorem to Arbitrary Hausdorff Topological Spaces.
Nikolai Makarov (Caltech): Some Facts and Questions Concerning Non-branching Aggregation in the Complex Plane.
Herve Queffelec (Universite de Lille 1): Some New Properties of Thin Sets of Integers in Harmonic Analysis.
Sheel Pandey (R.D. University Jabalpul): The Theory of Multipliers in Banach and Locally Convex Spaces.
Alexei Poltoratski (Texas A&M University): Maximal Properties of the Cauchy Transform.
Stanislav Smirnov (Yale University & KTH): Dimension of quasicircles and multifractal spectra.
Dirk Schlingemann (Erwin Schrödinger Institut): From Euclidean Field Theory to Quantum Field Theory.
Przemyslaw Wojtaszczyk (Uniwersytet Waszawski): Wavelets in H_2.

Continuation of the Program in the year 2000. The following scientists were invited: Franck Barthe, Philippe Biane, Miroslav Chlebik, Joe Diestel, Marian Fabian, Petr Holický, Bernd Kirchheim, Piotr Mankiewicz, Eva Matoušková, Vladimir Müller, Alain Pajor, Jan Pelant, Dénes Petz, Shlomo Reisner, Wilhelm Schlag, Thomas Schlumprecht, Carsten Schütt, Charles Stegall, Jay Barry Turett, Elisabeth Werner, Luděk Zajíček.

Nonequilibrium statistical mechanics

Organizers: G. Gallavotti (Rome), H. Spohn (München), and H.A. Posch (Vienna).

Total budget (including follow-up activities): ESI: ATS 709.000, external sources: ATS 21.000.

Dates: February – March, 1999.

Preprints contributed: [659], [675], [684], 2000: [843], [844], 2001: [1113] 2002: [1143], [1144], [1145], [1146], [1147], [1148], [1151], [1152], [1153], [1269].

Report on the program

In the original proposal, we planned to cover

- Gaussian thermostated dynamics,
- spatially extended dynamical systems,
- stochastic particle systems and growth processes,
- Hamiltonian dynamics.

We could attract specialists in the field and generate a stimulating research environment. The program included also a topical conference with many lectures by participants. A listing of these lectures is given below. However, we did not fully succeed in terms of stays beyond two weeks. The most obvious reason is that for most countries this period in February and March is in the middle of teaching.

It is not possible to cover all activities in such a summary. Instead, we take one or two representative topics from each of the four areas.

Stochastic particle systems and growth processes. (Derrida, Henkel, Krug, Landim, Olla, Redig, Schütz, Sidoravicius, Spohn, van Beijeren)

In a growth process a stable phase is growing at the expense of an unstable phase. On a macroscopic scale, the interface is flat and one is interested in the size and statistics of fluctuations. Around the time of the ESI workshop, this problem underwent spectacular advance. Baik, Deift, and Johansson could map the problem on random matrices and obtained explicit scaling functions, for the first time. Derrida had already analyzed the N-dependence of the corresponding large deviation function. We tried to understand how these approaches are related. We also used the exact time-dependent solution of Schütz for the asymmetric exclusion process to obtain directly the random matrix representation without the detour through the Schensted formula for Young diagrams. A related intensely discussed topic is how and if at all conformal invariance is relevant for growth processes.

Hamiltonian dynamics. (Bambusi, Bennettin, Bunimovich, Eckmann, Gallavotti, Gaspard, Cohen, Jauslin, Liverani, O. Penrose, Pillet, Posch, Rey-Bellet, Rondoni, Tel, Torcini)

Physically one expects that a small system coupled to an ideal, infinitely-extended reservoir at a definite temperature will approach equilibrium in the long-time limit. The list of models for which this can be proved is rather short. Even worse, the proofs are not stable against small, physically natural perturbations. A nonequilibrium variant is to couple the small system to two reservoirs at different temperatures. In the steady state there is a constant energy flux. The steady state is only indirectly determined and its statistical properties are poorly understood. The ESI discussions centered around the results by Eckmann, Pillet, and Rey-Bellet for flux through an anharmonic chain and the result by Liverani for a weakly anharmonic quantum oscillator.In the former case, a variant of the Gallavotti-Cohen fluctuation theorem was established. We tried to relax the so far rather strong conditions on the interaction potentials. In fact, the theory is really a considerable progress in the long-time limit for highly-singular nonreversible diffusion processes. In the quantum case one uses a careful iterative estimate on the time-dependent Born series to prove its convergence uniformly in time. The progress is that such estimates do not require any longer the exponential decay of the uncoupled two-point function.

Another important discussion developed about the hydrodynamic mode-like structures exhibited by the Lyapunov vectors, associated with the small (in the absolute sense) Lyapunov exponents, in the tangent space of many-body hard-disk and hard-sphere systems in and close to equilibrium. These modes are a consequence of the translation invariance of extended dynamical systems. They were found by computer simulation (Posch) and were unexpected. The discussions concentrated on the symmetries of these modes which show a hitherto not fully-understood multiplicity of the corresponding exponents. A simple random matrix model (Eckmann) was subsequently shown to exhibit weakly perturbed coherent long wavelength modes analogous to the simulation results.

Thermostated systems. (Bonetto, Cohen, Dorfman, Gallavotti, Hoover, Maes, Posch, Rateitschak, Rondoni, Spohn, Tel, Vollmer)

The Gallavotti-Cohen fluctuation theorem is one of the few general results for thermostated systems out of equilibrium. It considers the large deviations in the phase space volume contraction integrated along the trajectory of the system. Under the chaotic hypothesis, the odd part of the corresponding rate function is linear. The fluctuation theorem is global. So one important issue is whether and how one could prove a local version of the fluctuation theorem which is important in application to real systems. Numerically one often finds a linear odd part but with a slope different from the one predicted by the theory. The problem is then in which sense the chaotic hypothesis fails and whether it could be replaced by a weaker version still yielding a linear dependence. The fluctuation theorem is not restricted to deterministic systems out of equilibrium. In fact it holds also for stochastic systems. The large deviations are then for the time-integrated currents of the locally conserved fields. Maes explained us how the fluctuation theorem relates to general symmetries of space-time Gibbs measures. Towards the end of the workshop, rather unexpectedly, a lively discussion developed on the issue of steady versus non-steady fluctuation theorems. While the GC formulation is for the steady state, a similarly looking fluctuation theorem by Evans and Searles holds also for a rather special choice of the initial distribution with in essence no assumption on the dynamics. Thus, one has to understand whether the non-steady version is of any physical relevance and how the two versions are quantitatively related.

Another topic discussed in detail was the definition and identification of the hydrodynamic entropy production for dynamically thermostated systems, and the connection to the Evans-Searles and the Gallavotti-Cohen fluctuation theorem, relating the entropy fluctuations to the growth rate of the phase-space density, a generalization of the phase-space contraction rate. Also the role of non-dynamical but stochastic boundaries was investigated. It was demonstrated for a Brownian diffusion model that it is possible to formulate the tangent-vector dynamics such that the dissipative flux still determines the sum of the Lyapunov exponents which is related to the phase-space contraction rate. Experimentally, the dynamical randomness of Brownian motion has been analyzed in terms of an entropy per unit time (Gaspard). Although this interpretation has also been criticized, it nevertheless indicates that some of the novel measures of complex dynamics and microscopic chaos may also be obtained from experiment.

In conclusion, the workshop provided a platform for very lively discussions and scientific exchange. The field of nonequilibrium statistical mechanics is moving fast and some of the recently developed concepts provide a major step towards a better understanding of nonequilibrium processes. We are grateful to have been given the opportunity to organize this workshop and thank the Erwin Schrödinger Institute in Vienna for providing facilities and financial support.

Continuation of the program in 2000. In this continuation program there was the following conference: **Chaotic Dynamics and Dynamical Systems**, February 5 – 15.

Program:

E.G.D. Cohen (Rockefeller University): Dynamical systems in statistical mechanics.
W.G. Hoover (Univ. of California): SPAM Steady-State Shockwave Structure Simulations.
Harald A. Posch (Univ. Wien): Thermostated many-body systems.
R. Livi (Univ. di Firenze): Anomalous and Normal Heat Conduction in Lattices.
G. Schneider (Univ. Bayreuth): The stochastic Landau equation as an amplitude equation.
G. Gallavotti (Univ. di Roma): Irreversibility and entropy production.
G. Gentile (Univ. di Roma): The shape of the analyticity domain for the conjugating function of the standard map.
L. Rondoni (Politecnico di Torino): Equivalence of nonequilibrium ensembles and axiom C structures in 2-dimensional fluid mechanics.
A. Shirikyan (Herriot-Watt University, Edinburgh): A version of the Ruelle-Perron-Frobenius (RPF) theorem and applications.
R. Livi (Univ. di Firenze): Emergence of chaotic behaviour in linearly stable systems.
W.G. Hoover (Univ. of California): Quantum-thermostated hard disk.
C. Pillet (Univ. de Marseille): 'Natural' Non-Equilibrium Steady States for finite Quantum Systems.
W. Thirring (Univ. Wien): Gravitational collapse and Ergodicity in confined gravitational system: a discussion.
C. Dettmann (University of Bristol): Chaos and diffusion.
M. Wojtkowski (University of Arizona): Isoenergetic dynamics and Weyl connections.
S. Ciliberto (ENS Lyon): The pressure fluctuations of a turbulent wind verify the Gallavotti-Cohen fluctuation theorem.

H. Spohn (TU Muenchen): Statistical self-similarity of a nonequilibrium growth process.
F. Bonetto (Ecole Polytechnique Palaiseau): Properties of Stationary Nonequilibrium States in the Thermostated Periodic Lorentz Gas with many Weakly Interacting Particles.
S. Kuksin (Heriot Watt University Edinburgh): New proof of the uniqueness of an invariant measure for a randomly forced PDE.
C. Liverani (Universita di Roma): Toward ergodic properties of weakly non-linear disordered chain.
H. Van Beijeren (Utrecht University): Lorentz gas Lyapunov exponents on strong fields.
S. De Bievre (Universite de Lille): Motion of a classical particle in a vibration field: ohmic behavior.
H. Posch (Univ. Wien): Lyapunov modes.
S. Tcheremchantsev (Universite de Orleans): Generalized fractal dimensions of probability measures: definitions and basic properties.
M. Arndt (Univ. Wien): Quantum Interferences of Fullerenes: Perfect de Broglie Coherence of hot Molecules.
M. Pettini (Osservatorio Astronomica di Firence): Topology and Phase Transitions.

Invited scientists: Henk van Beijeren, Federico Bonetto, Sergio Ciliberto, E.G.D. Cohen, Stephan De Bievre, Carl Dettmann, Astrid De Wijn, Gianlorenzo Fagiolo, Christina Forster, Giovanni Gallavotti, Guido Gentile, Bill Hoover, Sergei Kuksin, Carlangelo Liverani, Roberto Livi, Christian Maes, Marco Pettini, Claude-Alain Pillet, Lamberto Rondoni, Guido Schneider, Armen Shirikyan, Herbert Spohn, Serguei Tcheremchantsev, Maciej P. Wojtkowski.

Holonomy Groups in Differential Geometry

Organizers: D. Alekseevsky, K. Galicki, and C. LeBrun.

Total budget (including follow-up activities): ESI: ATS 540.000, external sources: ATS 21.000.

Dates: .

Preprints contributed: [756], [769], [771], [779], [783], [796], [806], [816], [817], [821], [824], [827], [835], [839], [824], [827], [835], [839], [925].

Report on the program

The program opened with the **Second Meeting on Quaternionic Structures in Mathematics and Physics** which was held in Rome, September 6-10, 1999. Many participants of the holonomy program were also invited speakers at the Rome meeting. The conference was organized by Max Pontecorvo (Roma III) and Stefano Marchiafava and Paolo Piccinni (Roma I). The scientific committee consisted of D. Alekseevsky, K. Galicki, P. Gauduchon, S. Marchiafava, and S. Salamon. Many lectures were excellent and there was a lot of interaction between geometers and physicists. The meeting was a great success. A proceeding volume will be published electronically later by the EMS. More information about the conference with the full list of registered participants can be obtained from
`www.mat.uniroma3.It/users/max/meeting/meeting.html`.

After this very strong opening some of the participant moved to Vienna. The last visitors remained at ESI until the end of the year. Altogether about 50 participants visited the Institute this Fall. The following list of research topics pursued by the visiting participants during their stay in Vienna, even if not complete, should provide a brief summary of the scope of the program.

- classification of holonomy groups of torsion-free connections (Merkulov, Schwachhöfer).
- Kähler, Kähler-Einstein, CR geometry, momentum mappings (Alekseev, Alekseevsky, Bielawski, Bourguignon, Moroianu, Podesta, Spiro, Sergeev, Wiśniewski).
- quaternionic, hypercomplex, quaternion-Kähler, and hyperkähler manifolds (Alekseevsky, Barberis, Battaglia, Bielawski, Boyer, Dancer, Davidov, Dotti, Fino, Gauduchon, Galicki, Kobak, Pedersen, Poon, Singer, Swann, Verbitsky).
- locally conformal structures in complex and quaternionic geometry (Barberis, Dotti, Fino, Gauduchon, Marchiafava, Ornea, Piccinni, Pontecorvo).

- moduli spaces of connections over quaternion-Kähler and quaternionic manifolds. (Nitta)
- Sasakian-Einstein geometry and contact structures (Boyer, Friedrich, Figueroa, Galicki, Kath, Ornea).
- exceptional holonomy groups (Friedrich, Galicki, Kath, Semmelmann, Swann).
- holonomy reduction and Einstein manifolds (Boyer, Dancer, Galicki, Kobak, Mushkarov, Swann, Wang, LeBrun).
- twistor and spinor geometry, parallel spinors, Killing spinors (Baum, Baily, Calderbank, Eastwood, Friedrich, Kath, Moroianu, Semmelmann, Singer).
- holonomy reduction and string theory, special Kähler geometry, Frobenius manifolds, and other related topics (Agricola, Alekseevsky, Devchand, Cortés, Figueroa, Merkulov, Ogievetsky, Vandoren).
- Maldacena's Conjecture, near horizon geometries and holonomy group in physics (Figueroa, Vandoren, Ogievetsky, Devchand).

There were about 40 research talks during the program talks. It would be hard to choose just one key event in the program. We had many experts famous in their respective fields working on important and exciting research projects. We also had many young people just starting their scientific careers.

One should certainly mention here the lecture of Jarek Wiśniewski. He chose his visit for an announcement of a very important result in the field of Riemannian manifolds with special holonomy. All symmetric compact positive quaternion Kähler manifolds were classified over 20 years ago by Wolf. Ever since many people tried to find a non symmetric compact positive quaternionic Kähler manifold. More recently, LeBrun and Salamon used some of their rigidity results to conjecture that all such manifolds must be symmetric. Wiśniewski now claims to have the proof of the LeBrun-Salamon Conjecture. If the proof is correct it certainly will be one of the highlights of this wonderfully successful semester.

To give a few more examples, Claude LeBrun talked about his work on the existence and non-existence of supreme Einstein metrics, Uwe Semmelman's on his work on vanishing of Betti numbers on quaternion Kähler manifolds, and Sergei Merkulov's on his exciting results concerning Frobenius manifolds. José Figueroa gave an excellent series of lectures explaining to a mathematical audience how holonomy groups come up in modern supergravity theories. Thomas Friedrich spoke about his new work on weak holonomy in dimension 16 and the theme of weakening holonomy came back later in the talk of Andrew Swann. Sun Poon described his new results on the so-called HKT manifolds and Paul Gauduchon talked about Einstein 4-manifolds with hyperhermitian structures. Jean Pierre Bourguignon gave a beautiful lecture about spinors and special holonomy and Andre Moroianu spoke on parallel spinors on non-simply connected manifolds. Helga Baum and Ines Kath were describing their work on Killing spinors on pseudo-Riemannian manifolds. Charles Boyer talked about contact manifolds admitting Einstein metrics and Mike Singer about new hyperkähler manifolds in dimension 4. Armen Sergeev presented a twistor approach to the geometric quantization of some infinite-dimensional Kähler manifolds, for example, loop groups. McKenzie Wang spoke about integrability of cohomogeneity one Einstein equation, considered as a (finite dimensional) Hamiltonian system. Misha Verbitsky talked about trianalytic subvarieties of hyperKähler and hypercomplex manifolds and stated his surprising result that a submanifold of a hyperkähler manifold, which is complex with respect to a generic parallel complex structure, is 3-analytic and, hence, totally geodesic. All these, and many more, were truly first rate lectures, often describing completely new and exciting results.

Complex analysis

Organizers: F. Haslinger and H. Upmeier.

Total budget (including follow-up activities): ESI: ATS 684.000, external sources: ATS 1.000.

Dates: August–November, 1999.

Preprints contributed: [741], [749], [750], [762], [764], [766], [782], [786], [790], [795], [798], [799], [800], [803], [804], [808], [820], [822], [830], [834], [836], [855], [877], [880], [932], [967], [970], [987], [991], [1028].

Report on the program

The project started with the lecture of Adam Koranyi, whose contributions to complex analysis on symmetric spaces in combination with harmonic analysis were of great importance for the development of a rich and deep theory with far-reaching applications. In his report he explained some ideas how to generalize the theory of quasiconformal mappings to several variables which is of special interest for certain topics in theoretical physics.

The next activities concentrated on discrete group actions on Stein manifolds, invariant C-R operators, the Berezin transform and the problem of quantization (B. Krötz and G. Zhang). These topics met with a lively response from the parallel-running project on Applications of Integrability.

Three prominent scientists, B. Gaveau (Paris), P. Greiner (Toronto) and D. Tartakoff (Chicago) represented complex analysis methods in the theory of partial differential equations, such as the Hamilton-Jacobi equation, the transport equation, real Hamiltonian mechanics and regularity of sum of squares of real analytic vector fields.

The theory of CR-mappings found very much attention in the last years, the promising new results are presented in a recent Princeton Mathematical Series book by M. Baouendi, P. Ebenfelt and Linda Preiss Rothschild. In his address at ESI P. Ebenfelt gave an excellent survey of the most important new methods in this rapidly growing field. Interesting contribution to this subject were also delivered by A. Tumanov (extremal discs and regularity of CR mappings), B.Lamel (Segre sets) and R.Dwilewicz (extension of CR-mappings), G.Zampieri (analytic discs in symplectic spaces) and N.Shcherbina (Levi flat surfaces).

Between September 15 and October 15 the main activities on several complex variables took place. A series of survey talks by leading experts was organized : D.Barrett (Bergman kernels), K.Diederich (pluricomplex Green functions), I.Lieb (boundary values of the Neumann solution to $\overline{\partial}$), T. Ohsawa (L^2-holomorphic functions, extension and sampling), J.Leiterer ($\overline{\partial}$-cohomology), P.Pflug (completeness of Bergman and Caratheodory metrics). These survey talks were accompanied by reports on more special topics such as singularities of the Bergman kernel, Bochner -Hartogs theorems in the complex projective space, characterization of solvability and regularity of Lewy equations for special domains in $\mathbb{C}^2$, boundary behavior of Kobayashi metrics, convexifiability of finite type domains and q-complete spaces. It turned out that the participants found new and interesting insights in their own work by comments and remarks by other colleagues leading to a considerable output of preprints. At the end of this part of the project E.Straube, one of the last Bergman prize winners, gave an interesting survey talk on plurisubharmonic defining functions, vector fields and exactness of the winding form.

The link to the other part of the project was provided by the contribution of M.Englis on weighted Bergmann kernels and quantization. Here the main topics were symmetric spaces, C^*-algebras of Toeplitz operators, Hecke operators, application of quantization methods to the theory of modular forms, Berezin-Toeplitz quantization, the analysis of loop spaces, the spectrum of the hyperbolic Laplace-Beltrami operator, invariant domains in the complexification of a noncompact Riemannian symmetric space, B-functions on symmetric spaces, a microlocal version of Cartan-Grauert's theorem and Hermitian symmetric spaces and the Barlet-Koziarz method for holomorphic convexity.

Among the highlights of the part of the program devoted to the interactions between complex analysis and harmonic analysis, number theory and operator theory, were contributions by Y. Neretin (Moscow State University) on Beta-functions in several variables, J. Wolf (Berkeley) on representation theory via partially holomorphic functions, K.H. Neeb (Darmstadt) on infinite dimensional holomorphy on Grassmann flag manifolds, A. Unterberger (Reims) on modular functions and quantization of SL(2.R)-representations, T. Wurzbacher (Strasbourg) on Kaehler geometry of loop spaces, M. Schlichenmaier (Mannheim) on Toeplitz quantization of general Kaehler manifolds, L. Coburn (Buffalo) on Toeplitz operator algebras and applications to quantum mechanics and pseudodifferential calculus, and A. Sergeev (Steklov Institute) on general tube domains and envelopes of holomorphy. Also, several younger mathematicians (e.g., A. Alldridge and U. Hagenbach) presented important results on non-commutative Hardy spaces, while other participants, such as J. Arazy (Haifa), were mostly engaged in joint collaboration on new research projects, certainly an integral part of the activities at ESI-Seminars. It should be stressed that there were also fruitful interactions with the program on non-commutative geometry and mathematical physics directed by A. Alekseev, L.Faddeev, and H. Grosse.

Continuation of the program in the year 2000. This follow-up program was mainly devoted to the study of weakly pseudoconvex domains of finite type which were introduced in the attempt to generalize results and methods of the well understood case of strictly pseudoconvex domains. Important special topics in this connection are: boundary behavior of the Bergman and Szegö kernel, investigation of the corresponding $\bar{\partial}$-Neumann problem, compactness of the $\bar{\partial}$-Neumann operator, analytic hypo-ellipticity of pseudo-differential operators, CR-functions and manifolds and pluripotential theory. Another theme was weighted Bergman kernels and quantization.

Participants: J. D'Angelo (University of Illinois, Urbana), M. Englis (Prague University), G. Francsics (Columbia University, New York), Siqi Fu (University of Wyoming), M. Kolar (Brno University), W. Knirsch (Humboldt Universität, Berlin), B. Lamel (Royal Institute of Technology, Stockholm), O. Lemmers (Amsterdam University), Ewa Ligocka (Warsaw University), J. McNeal (Ohio State University),M. Schlichenmaier (Universität Mannheim), R. Sigurdsson (University of Iceland),E. Straube (Texas A& M University), D. Tartakoff (University of Illinois, Chicago).

Applications of Integrability

Organizers: A. Alekseev, L. Faddeev and H. Grosse.

Total budget (including follow-up activities): ESI: ATS 817.000, external sources: ATS .

Dates: August 15 - October 31, 1999.

Preprints contributed: [656], [676], [696], [698], [708], [723], [742], [743], [744], [745], [747], [751], [755], [758], [759], [760], [778], [784], [785], [791], [797], [802], [831], [832], [841], [842], [831], [832], [841], [842], [890].

Report on the program

The main topics that were considered in the program were as follows:

1. Completely integrable models and their applications to various fields of Physics.
2. Conformal Field Theory (CFT) and boundary CFT, applications to strings and D-branes.
3. Deformation quantization and path integrals.

The program was centered around three lecture series (3 lectures each) by the leading scientists participating in the program. Here is the brief description of these lecture series:

G. Felder gave a lecture course on his recent work explaining the universal deformation quantization formula of Kontsevich from the point of view of functional integral. His lectures attracted a lot of attention and, in particular, initiated an interaction with mathematicians visiting ESI at the same time. In particular, *L. Takhtajan* presented his work on deformation quantization of symplectic manifolds via the Bergmann kernel.

V. Schomerus presented a lecture series on his recent pioneering work relating D-branes to Noncommutative Geometry via boundary CFT. Several participants of the program presented talks on related topics and started collaborations which resulted in publications during the period of the program! In particular, *G. Felder* reported on his joint work with *J. Fröhlich, J. Fuchs and C. Schweigert* relating the boundary CFT to 3-dimensional topological field theory. Two groups, *A. Alekseev, A. Recknagel and V. Schomerus* and *K. Gawedzki and I. Todorov* published preprints on D-branes in the Wess-Zumino-Witten model.

L. Faddeev and A. Volkov gave a lecture series devoted to the new results in the quantum Liouville model. This is one of the most famous 2-dimensional models bridging between the theory of integrability and CFT. Other contributions on the Liouville model were presented by *B. Ponsot and J. Teschner.*

Among other important contributions one should mention the following two:

P. Wiegmann and A. Zabrodin published a preprint and presented a series of talks relating the classical problem of reconstructing a curve on a plane by its momenta with the integrable Toda hierarchy.

S. Lukyanov reported on his recent solution of the problem of a quantum wire with impurity. This is one of the fundamental problems of low-dimensional condensed matter which attracted a lot of attention during the last 20 years. A talk devoted to another interesting problem in the same field, the so-called *0.7 plateau* was presented by *V. Cheianov*.

The program initiated an extensive scientific exchange between the participants which resulted in a number of collaborations. Some of these collaborations led to contributions presented already during the program.

We would like to mention that our program got excellent support from the ESI staff.

Continuation of the program in the year 2000. The following scientists were invited: Anton Alekseev, Lioudvig Faddeev, Yvette Kosmann-Schwarzbach, John Madore, Andreas Recknagel, Alexei Rosly, Karl-Georg Schlesinger, Christoph Schweigert, Thomas Strobl, Anton Zabrodin.

Workshops organized outside the main programs

Winter school in geometry and physics

January 9–16, 1999, Srní, Czech Republic, with a contribution of ATS 10.000 from ESI. The proceedings were published in Suppl. Rend. Circ. Mat. Palermo, II. Ser. **63** (2000), 7–196.

Contents:

ESI - Workshop on Geometrical Aspects of Spectral Theory

Matrei in East Tyrol, Austria, July 5. This workshop was an offspring of two activities at ESI in 1998: Spectral Geometry (organized by L. Friedlander and V. Guillemin) and Schrödinger operators with magnetic fields (organized by I. Herbst, T. Hoffmann-Ostenhof and J. Yngvason). ESI contributed ATS 204.000, and the workshop resulted in the preprints [657], [658], [673], [674], [765], [768], [774], [833].

Participants: Thomas Østergaard Sørensen (Austria), Mark Ashbaugh (USA), Michiel van den Berg (UK), Leonid Friedlander (USA), Bernard Helffer (France), Ira W. Herbst (USA), Maria Hoffmann-Ostenhof (Austria), Thomas Hoffmann-Ostenhof (Austria), Thomas Kappeler (Switzerland), Frederic Klopp (France), Horst Knörrer (Switzerland), Peter Kuchment (USA), Ari Laptev (Sweden), Matthias Lesch (USA), Peter W. Michor (Austria), Sergey P. Novikov (Russia and USA), Kate Okikiolu (USA), Robert Seeley (USA), Zhongwei Shen (USA), Alexander V. Sobolev (UK), Thomas Østergaard Sørensen (Austria), Gerald Teschl (Austria), Steven Zelditch (USA), Maciej Zworski (USA).

Program:

Mark S. Ashbaugh: Some Eigenvalue Comparison Results for Domains in $\mathbb{S}^n$ and for Annular Domains in $\mathbb{R}^n$.
Michiel van den Berg and M. Lianantonakis: Asymptotics for the spectrum of the Dirichlet Laplacian on horn-shaped regions and Zeta- functions on cross-sections.
Leonid Friedlander: An inequality between Dirichlet and Neumann eigenvalues.
Bernard Helffer: Nodal sets for superconducting states in a non simply connected domain.
R. Froese and I. Herbst: Holonomic constraints in classical and quantum mechanics.
Thomas Hoffmann-Ostenhof: Multiplicity of eigenvalues of 2-dimensional Laplacians.
T. Kappeler and B. Mityagin: Estimates for periodic and Dirichlet eigenvalues of the Schrödinger operator.
Frédéric Klopp: Lifshitz tails for random Schrödinger operators with negative singular Poisson potential.
Peter Kuchment: Mathematics of photonic crystals.
Ari Laptev: New bounds on the constants $L_{\gamma,d}$ appearing in the Lieb-Thirring inequalities.
Matthias Lesch: A simple analytic proof of the gluing formula for the analytic torsion in the presence of a general (nonunimodular) flat bundle.
Peter W. Michor: Smooth perturbation theory of unbounded operators.
Sergey P. Novikov: Schrödinger Operators on Graphs and Symplectic Geometry.
Kate Okikiolu: Critical metrics for spectral Zeta functions.
Zhongwei Shen: Absolute Continuity of Periodic Schrodinger Operators.
Alexander V. Sobolev: On the Bethe-Sommerfeld conjecture for the polyharmonic operator.
Steven Zelditch: Hearing analytic plane domains with the symmetry of an ellipse.
Vesselin Petkov and Maciej Zworski: Breit-Wigner approximations

In the ESI-preprint [768] one can find abstracts of all talks, references, and collections of open problems.

Visitors outside the main programs

Visitors to ESI not associated with any of the main programs and workshops contributed the preprints [695], [716], [717], [720], [825], [843], [679], [680], [681], [692], [715], [716], [723], [730], [737], [748], [773], [775], [776], [788], [793], [794], [807], [810], [838], [847], [654], [660], [685], [740], [757], [761], [809], [840], [846], [663], [668], [669], [670], [672], [697], [754], [763], [767], [779], [781], [824], [827], [842], [722], [792], [801].

ESI spent ATS 858.000, with external contributions amounting to ATS 866.000.

The year 2000

General remarks

Management of the Institute

Honorary President: Walter Thirring
President: Jakob Yngvason
Directors: Peter Michor and Klaus Schmidt
Administration: Ulrike Fischer, Eva Kissler, Ursula Sagmeister
Computers: Andreas Čap, Gerald Teschl, Hermann Schichl

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Senior Research Fellows

In 2000 the Erwin Schrödinger Institute began to sponsor several 'Senior Research Fellowships' each year with the intention of inviting senior scientists for longer periods (up to 6 months in each calendar year) to strengthen not only its own scientific programme, but also the Austrian scientific infrastructure and, in particular, the graduate and post-doc programmes of the surrounding universities. Senior Fellows are offered a net salary of €3000/month and €750/month to invite visitors and organize small meetings.

The first two positions were offered to Vladimir Popov (August 1 – December 27, 2000) and Yurii A. Neretin (September 1 – December 20, 2000).

Budget and visitors: The budget of ESI for 2000 was ATS 10,74 Mio. (about €780.500). ATS 6,53 Mio. were spent on scientific activities and 5,7 Mio. on administration and infrastructure. Visitors supported from other (mainly non-Austrian) sources contributed the equivalent of a further ATS 1,26 Mio.

The number of scientists visiting the Erwin Schrödinger Institute in 2000 was 408, and the number of preprints was 157.

The year 2000 saw some controversial political changes in Austria. In response to the publicly expressed views of some prominent Austrian politicians the Erwin Schrödinger Institute put the following message on its web-page in February 2000.

Statement on Austria's current political situation

The political developments in Austria are viewed with great concern not only by the world media, but also by many Austrians.

The Governing Board and the Scientific Directors of the Erwin Schrödinger Institute would like to make it absolutely clear that they are totally opposed to the nationalistic, xenophobic, and racist sentiments expressed by some politicians of a party which is involved in Austria's new government.

The Institute will continue to do everything in its power to maintain and enhance international scientific interaction and exchange. We appeal to all our colleagues working abroad to continue to support the Institute in these endeavors.

Jakob Yngvason, President, Peter Michor and Klaus Schmidt, Scientific Directors.

Programs in 2000

Duality, string theory and M-theory

Organizers: H. Grosse, M. Kreuzer and S. Theisen.

Total budget (including follow-up activities): ESI: ATS 1.024.250, external sources: ATS 155.000.

Dates: March 15 - July 15, 2000.

Preprints contributed: [869], [872], [873], [884], [886], [898], [901], [903], [905], [907], [908], [909], [910], [911], [912], [913], [914], [915], [917], [924], [926], [927], [928], [931], [954], [955], [957], [958], [982], [998], [999], [1015], [1065].

Report on the program

The purpose of the program was to provide a meeting place for string theorists from around the world. This was indeed successfully accomplished. The participants came from 20 different countries (with many more nationalities).

For most of them this was their first visit to ESI. In this sense, our program gave further international visibility to the institute. In particular we were able to attract some of the leading experts in the subject.

All participants enjoyed their stay at the ESI and many of them expressed their interest in returning. They very much appreciated the good atmosphere and again and again mentioned the competence and helpfulness of the administrative staff.

As a start-up of the program we organized a short workshop (April 3 – 12). The talks of the workshop and during the rest of the program covered all recent developments in string theory, both on the formal and on the 'phenomenological' side. Below we give a very brief summary.

String vacua were until recently mainly discussed within the framework of closed string theories. Mirror symmetry has played a major rôle in these developments. Aspects of this were the subject of the seminars by Hosono and Skarke.

The realization that open and closed string theories are related via dualities has led to much activity in constructing string vacua within the type I theory. Here the incorporation of several background fields is possible. Recent results were presented in the seminars by Blumenhagen, Sagnotti, Stefanski.

Open string theories also provide new challenges to conformal field theory. Recent developments on boundary conformal field theory and their D-brane interpretation were presented by Schellekens, Schweigert, Walcher, Fuchs, Pawelczyk, Stanciu, Brunner. J. Distler gave two lectures on the K-theoretic description of D-branes.

The discussion of non-BPS D-branes was initiated by A. Sen. He presented some of his recent results of the fate of the tachyon in these backgrounds. While his discussion was within the recently resurrected framework of string-field theory, I. Sachs presented some results obtained from conformal field theory.

Another emphasis was on the AdS/CFT connection. Since the original proposal by Maldacena, many detailed calculations have been done to provide further evidence. Various aspects of this correspondence and some generalizations were presented by Petkou, Brandhuber, Arutyunov, Manvelyan, Polyakov, Skenderis and Lopez.

Parallel to our program there was also a ESI program on confinement. The particular interest of the Maldacena conjecture lies in the duality between a weakly coupled string theory and a strongly coupled gauge theory. As such it provides a theoretical framework for discussing questions such as confinement

in QCD. Gomez and Sonnenschein summarized the status of these connections and also presented new results.

On the more phenomenological side, the scenario with large extra dimensions, in particular within the framework of Randal and Sundrum, is of great interest recently. Various aspects of this have been discussed (Rey, Louis, Förste).

One of the main activities in string theory and other areas of mathematical physics is non-commutative geometry. The fact that turning on extra background fields in open string theories necessary leads to non-commutativity of space-time, has now attracted the attention of string theorists. We had seminars on this topic both by string theorists and by participants who have approached this subject from other directions, such as conformal field theory, quantum field theory on non-commutative spaces or quantum groups (Wess, Wulkenhaar, Landsteiner, Recknagel, Jurko, Schupp, Chu). A. Cattaneo gave two lectures on his work with Felder, where they present a 'physicists' approach to the quantization of poisson manifolds. As explained by Jurco, Schupp and Wess, this is the general setting of the so-called Seiberg-Witten map.

Other seminars covered black holes, matrix models, anomalies in string theory, duality in quantum field theories, aspects of conformal field theories, and many other aspects of string theory.

One of the highlights of the program was the Schrödinger Lecture by J. Polchinski (May 2), which attracted a large audience. We were asked to organize a second public lecture as part of the city hall lecture series. Since time before the summer break was too short, we could, unfortunately, not find a suitable speaker.

To summarize, we believe that our ESI workshop succeeded in bringing together a large number of scientists with interest in string theory and related areas and in creating a stimulating atmosphere with much discussion. Many of the preprints which were submitted contain the results of collaborations which were started at the ESI.

In addition to the funds provided by the ESI, one of us (S.T.) contributed funds from the European Community (DEM 20 000) to invite students and postdocs to the ESI and to cover the travel expenses of some of the visitors.

To conclude, we want to thank the ESI for giving us the opportunity to organize the program and to help in all possible ways to make it a successful one.

List of participants in 2000. Mohab Abou-Zeid, Ofer Aharony, Oleg Andreev, Gleb Arutyunov, Paolo Aschieri, Peter Bantáy, Ralph Blumenhagen, Andreas Brandhuber, Friedemann Brandt, Ilka Brunner, Alberto Cattaneo, Chong-Sun Chu, Jacques Distler, Harald Dorn, Sergey Fomin, Anamaria Font, Stefan Förste, Jürgen Fuchs, Beatriz Gato-Rivera, Cesar Gomez, Piotr Hajac, Sayed Fawad Hassan, Shinobu Hosono, Larisa Jonke, Branislav Jurčo, Topi Johannes Kärki, Elias Kiritsis, Sergei Kuzenko, Karl Landsteiner, Olaf Lechtenfeld, Wolfgang Lerche, Esperanza Lopez, Jan Louis, David Lowe, Dieter Lüst, John Madore, Ruben Manvelyan, Peter Mayr, Ruben Minasian, Thomas Mohaupt, Vitcheslav Mukhanov, David Olive, Ari Pankiewicz, Jacek Pawelczyk, Anastasios Petkou, Joseph Polchinski, Dimitri Polyakov, Norma Elisabeth Quiroz Perez, Eliezer Rabinovici, Voja Radovanović, Andreas Recknagel, Soo-Jong Rey, Markus Rosellen, Alexei Rosly, Ivo Sachs, Augusto Sagnotti, Emanuel Scheidegger, Norbertus Schellekens, Karl-Georg Schlesinger, Christof Schmidhuber, Peter Schupp, Christoph Schweigert, Adam Schwimmer, Claudio Scrucca, Ashoke Sen, Harald Skarke, Kostas Skenderis, Jacob Sonnenschein, Dmitri Sorokin, Bogdan Stefanski, Sonia Stanciu, Harold Steinacker, Stefan Theisen, Paul K. Townsend, Arkady Tseytlin, Johannes Walcher, Julius Wess.

Participants in 2001. Adam Schwimmer, Klaus Sibold, Stefan Theisen.

Confinement

Organizers: W. Lucha, A. Martin and F.F. Schöberl (Local organizer).

Total budget (including follow-up activities): ESI: ATS 319.000, no external contributions.

Dates: May-June, 2000.

Preprints contributed: [822], [885], [945], [969], [984], [985].

Report on the program

The non-Abelian nature of quantum chromodynamics (QCD), the quantum field theory describing strong interactions, prevents solutions to this theory in closed form: at present, it is neither possible to prove color confinement nor to understand hadron physics from first principles. Confinement of the color degrees of freedom, in particular, represents a physical phenomenon far beyond reach of perturbation theory. Consequently, in QCD the usefulness of perturbative techniques for evaluation of some quantum field theory is limited to the description of the short-range interaction whereas it is unavoidable to resort to nonperturbative treatments or to develop new approaches and techniques in order to deal with long-range interactions. Specifically, this programme was aimed at the following topics.

- exact bounds on energy eigenvalues;
- computational lattice quantum field theory.

Participants (name, date(s), research topic / title of talk).

Marshall Baker, 28. 06. - 08. 07. 2000, Dual QCD, Effective String Theory, and Regge Trajectories (Fred Zachariasen Memorial Lecture),
Bernd Berg, 24. 06. - 01. 07. 2000, U(1) Lattice Gauge Theory and Random Matrix Theory,
Michael Creutz, 09. 05. - 19. 05. 2000, Remarks on Domain-Wall Fermions, Hans Günter Dosch, 13. 06. - 27. 06. 2000, 16. 10. - 21. 10. 2000, Confinement and High-Energy Scattering,
Richard Hall, 11. 05. - 20. 05. 2000, Smooth Spectral Transition from Coulomb to Oscillator,
Urs Heller, 25. 06. - 01. 07. 2000, Chiral Symmetry on the Lattice: Recent Progress,
Christian B. Lang, 08. 05. - 12. 05. 2000, 22. 05. - 26. 05. 2000, Lattice Dirac Operators, Chiral Symmetry and the Finite Temperature Transition in QCD,
Pieter Maris, 21. 06. - 09. 07. 2000, Mesons as Bound States of Confined Quarks,
Harald Markum,
Topology and Chirality in QCD;, Random Matrix Theory and Quantum Chaos: from Super Conductor to Chromodynamics,
André Martin, 07. 06. - 11. 06. 2000, Does the Pion Satisfy the Klein-Gordon or the Salpeter Equation?,
Khin Maung Maung, 04. 05. - 01. 06. 2000, 02. 07. - 17. 07. 2000,
Claus Montonen, 07. 05. - 20. 05. 2000, Confinement in Supersymmetric Gauge Theories,
Martin G. Olsson,
Hugo Reinhardt, 29. 06. - 07. 07. 2000,
Craig D. Roberts, 10. 06. - 25. 06. 2000, 01. 07. - 07. 07. 2000, Dyson-Schwinger Equations and Continuum Strong QCD,
Shasaka M. Roy, 01. 05. - 05. 06. 2000, Maximally Realistic Causal Quantum Theory,
Virendra Singh, 10. 05. - 28. 05. 2000,
Peter Tandy, 20. 06. - 08. 07. 2000, Chiral Symmetry Restoration, Deconfinement, and Meson Correlations at Finite T,
Nils A. Törnqvist, 05. 05. - 19. 05. 2000, Trying to Understand the Lightest qq-bar Scalar Mesons, and Especially the Controversial sigma(400-1200),
Anthony Williams, 25. 06. - 08. 07. 2000, Gauge Fixing and Gluon and Quark Propagators on the Lattice,
Francisco José Yndurain, 14. 06. - 30. 06. 2000, 11. 02. - 24. 02. 2001, Heavy Quarkonium in QCD; The b Quark Mass From Spectroscopy; Properties of Bottomium from QCD.

Participants in 2001. Richard Hall, Francisco J. Yndurain.

The publication of the proceedings of the totality of the lectures given within this programme is in preparation (publisher: World Scientific Publishing Co., Singapore).

As a complementary activity, the International Conference on **Quark Confinement and the Hadron Spectrum IV** was held from July 3 to July 8, 2000 at the Austrian Academy of Sciences with Wolfgang Lucha as Chairman.

Program:

Poul Henrik Damgaard (Niels Bohr Institute): The Infrared Limit of the Dirac Operator Spectrum: Exact Results.
Xue-Qian Li (Nankai University, Tianjin): Application of the Hypervirial Theorem.
Craig D. Roberts (Argonne National Lab): Contemporary Applications of Dyson-Schwinger Equations.
Lorenz von Smekal (Erlangen): What the Infrared Behaviour of QCD Green Functions Can Tell Us About

Confinement in the Covariant Gauge.
Valentine I. Zakharov (MPI, Munich): Nonperturbative Effects at Short Distances in QCD.
Oliver Keith Baker (NuHEP, Hampton): Strangeness Production Using Electrons.
Marshall Baker (Seattle): Dual QCD, Effective String Theory, and Regge Trajectories (Fred Zachariasen Memorial Lecture).
Stephen R. Cotanch (North Carolina State University): Relativistic Many-Body Approach to Mesons, Hybrids and Glueballs.
Gilberto Colangelo (Zürich): Recent Progress in Chiral Perturbation Theory.
Herbert Neuberger (Rutgers University): Exact Chiral Symmetry with a Non-Perturbative Cutoff.
José Emilio Fernandes Tavares Ribeiro (Lisbon): The Role of Chiral Symmetry in Hadronic Scattering.
Anthony G. Williams (Adelaide): Lattice Studies of Confinement and Chiral Symmetry Breaking in a Covariant Gauge.
Stephan Olejnik (Bratislava): Center Vortices and Color Confinement in Lattice QCD.
Hugo Reinhardt (Tübingen): Magnetic Monopoles, Center Vortices, and Topology of Continuum Yang-Mills Theory.
Pieter Maris (Kent State University): Continuum QCD and Light Mesons.
Federico Antinori (INFN, Padova) Recent Results from the CERN-SPS Heavy-Ion Programme
Thomas Devlin (Rutgers University): The Last Meson.
Hugh Philip Shanahan (Tsukuba): The Bc and Other Bottom Hadrons From Heavy Quark Lattice Field Theory.
Chris Michael (Liverpool): Hybrids, Glueballs, Exotic States from the Lattice.
Mikhail Shifman (Minnesota): Lessons for QCD from Supersymmetry.
Gunnar Bali (Glasgow): QCD Potentiology.
Antonio Vairo (Heidelberg): Potential NRQCD: An Effective Theory for Heavy Quarkonium.
Zoltan Ligeti (Fermilab): CKM Matrix Elements from B Decays.
Howard Georgi (Harvard): Concluding Talk.

Representation theory

Organizers: V. Kac, A. Kirillov and P. Michor (local organizer).

Total budget (including follow-up activities): ESI: ATS 963.450, external sources: ATS 61.000.

Dates: April – Juli, 2000.

Preprints contributed: [857], [878], [887], [888], [893], [899], [900], [906], [916], [920], [921], [922], [929], [939], [941], [964], [973], [976], [983], [995], [1023], [1024], [1025], [1045], [1111], [1112], [1114], [1115], [1131], [1132].

Report on the program

There have been a number of remarkable developments in representation theory in the past few years. The objective of the programm was to review these developments and to discuss the interrelations between them and future developments.

One of the most remarkable features of the recent progress in representation theory is a very strong influence of theoretical physics, especially conformal field theory and the theory of integrable models. This has been reflected in a series of talks by A. Kirillov Jr. on modular functors and topological field theories, by P. Eting of on dynamical quantum groups and of E. Frenkel on vertex algebras and algebraic curves, and of talks by V. Ginzburg on Calogero models and double affine Hecke algebras, by A. Givental on Frobenius manifolds, by A. Zabrodin on inverse potential problem, by C. Teleman on representations at critical level, by A. Okunkov on application of representation theory to combinatorics of algebraic curves, and several others.

A new development in representation theory with potential applications to the Standard Model was discussed in a talk by Rudakov on his work with Kac about representation of exceptional infinite - dimensional Lie superalgebras. A remarkable application of the K-functor for quiver varieties to the characters of affine quantum groups was reported by H. Nakajima, along with a related talk by E. Vasserot.

More traditional, but no less remarkable topics were discussed in a series of talks by A. N. Kirillov, A. Fomin and A. Zelevinski on combinatorial aspects of representation theory and by A. Klyachko on application of the theory of symmetric spaces and random walks to the solution of the old Thompson

problem on the distribution of eigenvalues, in a talk by A. Borodin and G. Olshanski on spherical representations of the infinite unitary group, and in a talk by M. Vergne on orbit method.

There were on average two talks every Monday, Wednesday and Friday, leaving Tuesdays and Thursdays free for discussions and sightseeing. Almost all talks were concluded by a lovely discussion.

Participants. Anton Alekseev, Vladimir Baranovsky, Philippe Biane, Alexey Borodin, Alessandro D'Andrea, Vladimir Dergachev, Alberto De Sole, Michel Duflo, Pavel Etingof, Alice Fialowski, Edward Frenkel, Victor Ginzburg, Alexander B. Giventhal, Victor Kac, Jerry Kazdan, Sergei Khoroshkin, Alexandre Kirillov, Alexander Kirillov Jr., Anatoli Kirillov, Alexander Klyachko, Dimitri Leites, Grigori Litvinov, Yavor Markov, Andrei Mironov, Alexander Molev, Aleksei Morozov, Hiraku Nakajima, Maxim Nazarov, Masatoshi Noumi, Andrei Okounkov, Grigory Olshanskiy, Eric Opdam, Alexander Panov, Irina Paramonova, Nicolai Reshetikhin, Natasha Rojkovskaia, Alexei Rudakov, Alexander Sergeev, Petr Somberg, Matthew Maciej Szczesny, Constantin Teleman, Eric Vasserot, Michéle Vergne, Anatoly Vershik, Minoru Wakimto, Anton Zabrodin, Andrei Zelevinsky.

Algebraic groups, invariant theory and applications

Organizers: B. Kostant, F. Pauer, V. Popov and P. Michor (local organizer).

Total budget (including follow-up activities): ESI: ATS 962.000, external sources: ATS 5.000.

Dates: August 1 – December 29, 2000.

Preprints contributed: [938], [943], [946], [956], [966], [972], [978], [978], [983], [993], [994], [996], [1000], [1001], [1066], [1133].

Report on the program by V. Popov

The Program covered all topics according to its plan.

Many of the visitors of this program are leading experts in the subject and prominent scientists. Altogether there were delivered 88 talks. Practically every week there were at least three 90 minutes talks, usually on Monday, Wednesday and Friday. In August–September there were two 90-minutes talks every Monday, Wednesday and Friday.

The following major trends and topics were covered by the Program.

- Theory of embeddings of algebraic homogeneous spaces. Varieties of complexity 0 and 1.
- Spherical varieties: classification, algebro-geometric properties and combinatorial invariants. Wonderful varieties: properties and classification for type A. Affine smooth spherical varieties, Delzant conjecture.
- Explicit models of wonderful compactifications of classical groups: linear relations, hinges, exterior algebras and Berezin transformations.
- Spherical varieties and multiplicity free hamiltonian actions.
- Stability of actions.
- Affine embeddings with finitely many orbits.
- Symmetric varieties and groups with involutions.
- Hilbert's 14th problem and the related geometric problems.
- Algebraic differential operators. Invariant differential operators and multiplicity free actions. Applications to combinatorics.
- Abelian ideals in unipotent radicals of parabolas and the Bott–Borel–Weil theorem.

- Classical Invariant Theory: old and new (a survey). The symbolic method and constructive Invariant Theory. Classical Invariant Theory for covariants. Classical Invariant Theory for nonclassical groups: invariant algebras and an analogue of M. Artin's conjecture. 'Nice' properties in Invariant Theory. A symbolic methodology for all semisimple groups via realizing coordinate ring of flag varieties inside that of Borel.
- Computational Invariant Theory.
- Homological properties of algebras of invariants.
- Group actions in physics: representations of groups and semigroups in rigged Hilbert spaces.
- Essential dimension of algebraic groups.
- Equivariant symplectic geometry. Invariant linear connections on homogeneous symplectic varieties.
- Weakly symmetric and commutative homogeneous spaces.
- Cohomology of braid and Artin's groups.
- Applications of algebraic group actions to combinatorics: $n!$-conjecture.
- Quiver varieties.
- Generic algebras: discriminants and quasiderivations.
- Algebraic quotients: theory of good quotients.
- Complex analytic supermanifolds and homogeneous spaces. Homogeneous vector bundles and supermanifolds associated with complex flag manifolds.
- Principal nilpotent pairs in simple Lie algebras.
- Normality of nilpotent varieties. Geometry of nilpotent cone in positive characteristic and the cotangent bundle of flag varieties
- Products of conjugacy classes in algebraic groups and the related topics.
- Semistable bundles on algebraic curves in positive characteristic and low hight representations.
- Moduli spaces of principal bundles over a smooth projective curve and the Luna strata of algebraic group actions.
- Steinberg modules, good filtrations, and invariants of symmetric algebras.
- Combinatorics of systems A_r and volumes of flow polytopes.
- Invariant theoretic methods in Jacobian problem and in the theory of mathematical instantons.
- Discrete groups generated by complex reflections: classification and properties.
- Spetses – objects whose Weyl group is a finite complex reflection groups.
- Schubert varieties: smooth points and the Peterson map; equivariant cohomology, torus actions and Springer fibers.
- Division algebras and rationality.
- Quantum Invariant Theory: nonstandard deformations of enveloping algebras of $\mathcal{U}(\mathfrak{so}(n))$, their structure, invariants and q-harmonic polynomials.
- Cayley mappings for algebraic groups.

List of participants. Ivan Arzhantsev, Andrzej Bialynicki-Birula, Arno Bohm, Abraham Broer, Romain Camus, James B. Carrell, Corrado De Concini, Alexandre Elashvili, Nikolai Gordeev, William J. Haboush, Sergei Igonin, Pavel Katsylo, Gregor Kemper, Anatoliy Klimyk, Vsevolod Kordonski, Bertram Kostant, Hanspeter Kraft, Shrawan Kumar, Jochen Kuttler, Dominique Luna, Gunter Malle, Vikram B. Mehta, Arkadi Onishachik, David J. Saltman, Yasmine Sanderson, Gerald Schwarz, Dimitri Shmelkin, Tonny Albert Springer, Elisabetta Strickland, Evgueni Tevelev, Dmitri Timashev, Michéle Vergne, Dayanand Verma, Ernest Vinberg, Nolan Wallach, Sujeewa Wickramasekara.

Continuation of the program in 2001. As a continuation of this program the following conference was organized in 2001.

Conference on interesting algebraic varieties arising in the theory of algebraic groups, October 22 – October 26 2001.

Program:

D. Saltman (University of Texas at Austin, USA): Invariants of symmetric and orthogonal groups of degree 8, 10.22.
D. Snow (University of Notre Dame, USA): The role of exotic affine spaces in the classification of homogeneous affine varieties, 10.22.
N. Gordeev (Pedagogical University, Russia): Branch locus of quotients of finite group actions, 10.22.
A. Parshin (Steklov Institute, Russia): The Krichever correspondence for algebraic varieties, 10.23.
C. Procesi (University Rome-1, Italy): Diagonal harmonics, 10.23.
F. Zak (CEMI, Russia): Orders and classes of projective varieties, 10.23.
C. De Concini (University Rome-1, Italy): On semigroups associated to irreducible representations of algebraic groups, 10.24.
J. Landsberg (Georgia Institute of Technology, USA): Deligne dimension and decomposition formulas from a geometric perspective, 10.24.
V. Popov (Moscow Technical University MGIEM, Russia): Self-dual algebraic varieties, Lie algebras, and symmetric spaces, 10.24.
C. Ciliberto (University Rome-2, Italy): Varieties with one apparent double point, 10.25.
H. Nicolai (Albert-Einstein-Institut, Golm): BKL dynamics and hyperbolic Kac-Moody algebras , 10.25.
L. Manivel (Institute Fourier / Grenoble, France): The singularities of Schubert varieties, 10.25.
S. Mukai (Nagoya University, Japan): Minimal counterexample to Hilbert's 14th problem, 10.25.
E. Tevelev (Moscow Independent University, Russia): Rank stratification of the tangent space of G/P, 10.26.
J.-M. Hwang (KIAS, South Korea): Automorphism groups of the spaces of lines on projective manifolds with Picard number 1, 10.26.
N. Mok (University of Hong-Kong, Hong-Kong): Holomorphic vector fields and deformation rigidity, 10.26.

Participants. Ciro Ciliberto, Corrado De Concini, Nikolai Gordeev, Jun-Muk Hwang, Joseph M. Landsberg, Laurent Manivel, Ngaiming Mok, Shigeru Mukai, Alexey Parshin, Claudio Procesi, David J. Saltman, Dennis Snow, Evgueni Tevelev.

Quantum measurement and information

Organizers: A. Zeilinger, A. Eckert and Peter Zoller.

Total budget (including follow-up activities): ESI: ATS 990.000, external sources: ATS 200.000.

Dates: September - December, 2000.

Preprints contributed: [904], [947], [949], [950], [962], [963], [977], [981], [988], [1006], [1019], [1035], [1036], [1041], [1080].

Report on the program by A. Zeilinger

Through the ESI programme which I coordinated some of the leading figures within the field of quantum information were given the possibility to come to Vienna. A certain problem was presented by the fact that this field is currently in an adiabatic phase of expansion, and the number of programmes and workshops being organized world-wide is so great that it is very difficult to win leading figures. This explains the fact that the co-organizers Artur Ekert and Peter Zoller were only able to be present

in Vienna for either a very short time or not at all. Considering this difficulty it is noteworthy that some of the best international figures did indeed come. This was made easier by the organisation of the conference in commemoration of John Bell, to mark the 10th anniversary of his death, within the programme, which was clearly particularly attractive. During the Bell conference it was possible to bring many young physicists into personal contact with some of the leading figures in the field, particularly those participants coming from Eastern Europe for the first time. The fact that during this conference no registration fee was charged was seen as very positive by many of these young people, who otherwise would not have been able to attend. Among the scientific successes were the discussions of new ways of carrying out quantum purification and the characterization of high-dimensional entangled states. As one of the participants commented, 'now Vienna is definitely on the map' in this subject.

TMR-Network meeting 'The Physics of Quantum Information', September 3 - 6, 2000. This meeting was held on the first three days of the program 'Quantum measurement and information'.

Program:

Michel Brune: Step by step multi particle entanglement in a cavity QED experiment.
Ben Varcoe: Fock states Rabi oscillations; a building block for the observation of new phenomena in quantum optic.
Nicolas Gisin: A useful coherent quantum measurement.
Massimo Palma: Dynamic and geometric quantum computation with josephson qubits.
Ferdinand Schmidt-Kaler: Quantum information processing with Ca+-Ions.
Paul Barton: Ground state coupling of ion strings.
Giovanna Morigi: Sympathetic cooling and quantum logic with Indium-Magnesium ion chain.
Karl Schulze: Continuos source of cold atoms for quantum computation.
Dik Bouwmeester: Error-free optical quantum communication and stimulated entanglement.
Jian-Wei Pan: Two- and four-photon entanglement purification with linear elements.
Günther Mahler: Fundamental limits of control: a quantum approach to second law.
Peka Lathi: Covariant phase observables in quantum mechanics.
Vlatko Vedral: Quantum Distinguishability and Information Processing.
Stig Stenholm: Quantum electronics in groovy structures

Quantum [un]speakables. Conference in commemoration of John S. Bell. November 10 – 14, 2000. This conference was organized within the framework of the Program 'Quantum measurement and information' to commemorate John S. Bell, who died 10 years ago, and aimed to cover all the scientific activities of John Bell.

Program:

Abner Shimony: Recollections and Reflections on Bell's Theorem.
John Clauser: Early History of Bell's Theorem.
Roman Jackiw: Descendants of the Chiral Anomaly.
Andrew Whitaker: Education and Early Years.
Jack Steinberger: Personal Recollections.
Bernard d'Espagnat: My Interaction with John Bell.
Antonino Zichichi: John Bell and the 10 Challenges of Subnuclear Physics.
Michael Horne: Interactions with John Bell on the Nonlocality Problem.
Gerard t Hooft: Quantum Mechanics and Determinism at the Planck Scale.
Stig Stenholm: Information and Meaning. How Physical are They?
Alain Aspect: Bell's Theorem: The Naive View of an Experimentalist.
Reinhold Bertlmann: Magic Moments: A Collaboration with John Bell.
Mary Bell: Reminiscences of John Bell.
Helmut Rauch: Towards More Quantum Complete Neutron Experiments.
Ed Fry: A Novel Definitive Test of Bell Inequalities; an Experimental Realisation of the EPR-Gedankenexperiment with Spin-One-Half-Nuclei.
Anton Zeilinger: Bell's Theorem and Quantum Information.
Eduardo de Rafael: From Vector Meson Dominance to Large-Nc QCD.
Simon Kochen: Geometry and Quantum Mechanics.
Jon Magne Leinaas: Thermal Excitations of Accelerated Electrons.
Ramamurti Rajaraman: Fractional Charge.
David Sutherland: Precursors of the Chiral Anomaly.
Charles Bennett: Storage and Retrieval of Classical Information in Multipartite Quantum Systems.
Berge Englert: Quantification and Characterization of Entanglement.
Hans Kleinpoppen: Coherence Effects and Ultrashort Time Correlations of Two-Photon Radiation of the Metastable State of Atomic Hydrogen.

Franco Selleri: Theories Equivalent to Special Relativity.
Gregor Weihs: Bell's Theorem for Space-Like Separation and GHZ.
Nicolas Gisin: Test of Relativistic Quantum State Collapse with Moving Reference Frame.
Ian Percival: Speakable and Unspeakable after John Bell.
GianCarlo Ghirardi: John Bell and the Dynamical reduction Program.
Artur Ekert: The Bell Theorem in Quantum Cryptography.
Roger Penrose: Quantum State Reduction, Gravitation and Quanglement.

Participants. Paolo Aniello, David Marcus Appleby, Vladan Arsenijević, Alain Aspect, Almut Beige, Mary Bell, Charles Bennett, Rodolfo Bonifacio, Dagmar Bruss, Vladimir Buzek, William Case, Ignacio Cirac, John Clauser, Eduardo De Rafael, Edib Dobardžić, Shahar Dolev, Luming Duan, Miloslav Dušek, Artur Ekert, Alexandre Elashvili, Avshalom C. Elitzur, Berthold-Georg Englert, Bernard d'Espagnat, Ed Fry, Cristopher A. Fuchs, Giancarlo Ghirardi, Nicolas Gisin, Lov K. Grover, Guangcan Guo, Daniel Greenberger, Hanno Hammer, Fedor Herbut, Gerardus t'Hooft, Michael Horne, Michal Horodecki, Pawel Horodecki, Ryszard Horodecki, Zdenek Hradil, Roman W. Jackiw, Christian Jäkel, Richard Josza, Anders Karlsson, Erik Karlsson, Dagomir Kaszlikowski, Julia Kempe, Sergei Kilin, Hans Kleinpoppen, Ladislav Kocbach, Simon Kochen, Barbara Kraus, Gershon Kurizki, Pekka Lahti, Jan Ake Larsson, Walter E. Lawrence, Jon Magne Leinaas, Maciej Lewenstein, Chi-Kun Lin, Elena Loubenets, Stephen Lovesey, Gúnter Mahler, Johnjoe McFadden, Gerard Milburn, Jiannis Pachos, Nikola Paunković, Mladen Pavicic, Roger Penrose, Ian Percival, Itamar Pitowsky, Martin Plenio, Sandu Popescu, Slobodan Prvanović, Claudio Procesi, Jagdish Rai, Suranjana Rai, Ramamurti Rajaraman, Zinovy Reichstein, Terry Rudolph, Barry Sanders, Franco Selleri, Abner Shimony, Salvatore Solimeno, Stig Stenholm, Chang-Pu Sun, Kalle-Antti Suominen, David Sutherland, David Tannor, Paolo Tombesi, Constantino Tsallis, Tomáš Tyc, Lev Vaidman, Vlatko Vedral, Guifré Vidal, Mingsheng Zhan, Mário Ziman, Marek Zukowski.

Workshops organized outside the main programs

Winter school in geometry and physics

January 9–16, 2000, Srní, Czech Republic, with a contribution of ATS 10.000 from ESI. The proceedings were published in Suppl. Rend. Circ. Mat. Palermo, II. Ser. **66** (2001), 7–218.

Contents:

Wolfgang Pauli und die Physik des 20. Jahrhunderts

April 12-13, 2000. This conference to commemorate Wolfgang Pauli's 100th birthday was held in German, and was organized jointly by ESI, Universität Wien, Österreichische Physikalische Gesellschaft, Bundesministerium für Bildung, Wissenschaft und Kultur, Magistrat der Stadt Wien. The scientific committee consisted of H. Rauch, W. Thirring, J. Yngvason, A. Zeilinger, and the meeting was organized by W. Reiter, J. Yngvason and A. Zeilinger.

Programm:

Franz v. Feilitzsch, München: Dunkle Materie und die Zukunft des Universums. Abendvortrag als 'Wiener Vorlesung' im Rathaus, Großer Sitzungssaal des Stadtsenats, mit einer Einführung von H. Pietschman.
Charles P. Enz, Zürich: Facetten aus Paulis Leben und Werk.
Karl v. Meyenne, München: Die Entstehung des Ausschließungsprinzips und seine frühen Anwendungen.
Francis Halzen, Univ. Wisconsin, Madison, USA: Neutrino Vision: From Quarks to the Universe.
Klaus Fredenhagen, Univ. Hamburg: PCT, Spin und Statistik: Physikalische Prinzipien und ihre Konsequenzen.
Valentin L. Telegdi, Zürich: Paulis große Überraschung - die Paritätsverletzung.
Walter Thirring, Univ. Wien: Makroskopische Auswirkungen des Pauli-Prinzips.
Victor F. Weisskopf, Cambridge, USA: Erinnerungen eines Pauli-Assistenten.

Summer Session Seminar Sophus Lie

ESI hosted the Sophus Lie Seminar Summer Session on May 26 and 27, 2000. This Seminar meets twice a year in varying locations in Germany, Austria and Poland.

Programm:

A. Kirillov (Pennsylvania), Introduction to root systems.
K.H. Hofmann (Darmstadt), Arc components of compact groups are Borel sets, aren't they?
P.W. Michor (Vienna), Geometry of orbit spaces of Riemannian transformation groups.
A. Cap (Vienna), Curved analogs of the Bernstein-Gelfand-Gelfand resolution.
H. Biller (Darmstadt), Actions of Compact Groups on Rational Cohomology Manifolds.
D. Mittenhuber (Darmstadt), Controllability of solvable Lie algebras.
A. Kirillov (Pennsylvania), Family algebras.
W. Wojtynski (Warsaw), Groups of strings and their Lie theory.
M. Palese (Torino), Remarks on the Geometry of Baecklund Transformations.
N. Reshetikhin (Berkeley), Applications of Lie Theory to Integrable Systems.
M. Wüstner (Darmstadt), A generalization of the Jordan decomposition.
P. Maier (Darmstadt), New results on Frobenius groups admitting planar Partitions.

List of participants: H. Biller (Darmstadt), B. Breckner (Vienna), A. Cap (Vienna), M. Dickten (Darmstadt), H. Führ (Sophia), H. Glöckner (Darmstadt), W. Herfort (Vienna), K.H. Hofmann (Darmstadt), A. Kirillov (Philadelphia), P. Maier (Darmstadt), P.W. Michor (Vienna), D. Mittenhuber (Darmstadt), M. Neuhauser (München), M. Palese (Torino), D. Poguntke (Bielefeld), N. Reshetikhin (Berkeley), W.A.F. Ruppert (Vienna), A. Strasburger (Warschau), H. Welk (Leipzig), W. Wojtynski (Warschau), M. Wüstner (Darmstadt).

Visitors outside the main programs

Visitors to ESI not associated with any of the main programs and workshops contributed the preprints [852], [853], [889], [971], [974], [825], [843], [864], [944], [953], [979], [838], [847], [848], [854], [856], [858], [867], [868], [876], [882], [892], [896], [897], [934], [940], [948], [951], [959], [960], [965], [990], [840], [846], [850], [857], [870], [895], [899], [935], [936], [824], [827], [842], [874], [881], [891], [902], [918], [919], [923], [930], [933], [942], [980], [982], [851], [865], [937], [989]. This lists includes preprints contributed by the Senior Research Fellows and their collaborators.

ESI spent ATS 831.500, with external contributions amounting to ATS 456.500.

Guests of A. Cap. Jarolim Bureš, Rod A. Gover, Adam Harris, Gerd Schmalz, Jan Slovák, Vladimir Souček.

Guests of P. Michor. Dmitri Alexeevski, Franz W. Kamber, Alexander Klyachko, Mark V. Losik, Shahn Majid, Gerard Misiolek, Niall O'Murchadha, Arkadi Onishachik, Dénes Petz, Vladimir L. Popov, Konstanze Rietsch, Alexei Rudakov, Cornelia Vizman, Shoji Yokura.

Guests of K. Schmidt. Rajendra Bhatia, Thomas Cusick, David E. Evans, Krzysztof Fraczek, Rajinder Hans-Gill, Oliver Jenkinson, Mariusz Lemańczyk, Hitoshi Nakada, Barry Sanders, Károly Simon, Selim Tuncel, Anatoly Vershik.

Guests of W. Thirring. Nevena Petrova Ilieva-Litova, Dmitri Petrina.

Guests of J. Yngvason. Christoph Adam, Hellmut Baumgärtel, Piotr Bizoń, Hans-Jürgen Borchers, Soren Fournais, Klaus Fredenhagen, Hendrik Grundling, Francis Halzen, Kristinn Johnsen, Elliott Lieb, John Madore, Dmitri Petrina, Bert Schroer, Dmitri Vassilevich.

The year 2001

General remarks

Management of the Institute

Honorary President: Walter Thirring
President: Jakob Yngvason
Directors: Peter Michor and Klaus Schmidt
Administration: Maria Windhager, Eva Kissler, Ursula Sagmeister
Computers: Andreas Čap, Gerald Teschl, Hermann Schichl

International Scientific Advisory Committee

Jean-Pierre Bourguignon (IHES)
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Viktor Kac (MIT)
Elliott Lieb (Princeton)
Harald Niederreiter (Singapore)

Senior Research Fellows

Anoton Alexeev (May 16 – July 2)
Shrikrishna G. Dani (March 22 – August 31)
Yurii A. Neretin (May 3 – June 29 and November 5 – December 31)
Ivan Todorov (February 1 – May 31 and November 1 – December 31)
Anatoli Vershik (March 1 – March 15 and October 16 – December 15)

Budget and visitors: The budget of ESI for 2001 was ATS 10,74 Mio. (about €780.500); of these ATS 7,5 Mio. were spent on scientific activities and 3,7 Mio. on administration and infrastructure. Visitors supported from other (mainly non-Austrian) sources contributed the equivalent of a further ATS 1,537 Mio.

The number of scientists visiting the Erwin Schrödinger Institute in 2001 was 460, and the number of preprints was 138.

Programs in 2001

Scattering theory

Organizers: V. Petkov, A. Vasy and Maciej Zworski

Total budget (including follow-up activities): ESI: ATS 980.000, external sources: ATS 208.000.

Dates: March – July, 2001.

Preprints contributed: [1040], [1044], [1048], [1052], [1067], [1068], [1073], [1091].

Report on the program

Review of the goals of the program. The purpose of the program was to bring together experts with different perspectives in scattering theory with particular emphasis on the following areas.

- Scattering theory in settings where there are singularities at infinity: the N-body problem and higher rank locally symmetric spaces.
- Resonances which describe scattering states which oscillate at some frequency (or have some rest energy) and decay at some rate.
- *Quantum chaos* in the context of scattering.
- Scattering theory in modern physics

Workshops. The program had two formal workshops and an informal one: in March, May and July respectively. Almost all invited participants attended and the May workshop was particularly large and lively. In July, there were 15 participants in residence and that lead to a series of interesting talks (by Sjoestrand, Sigal, Stoyanov, Dimassi, Zerzeri, Petkov, Vasy, and Zworski) which amounted to an informal workshop.

The talks during the workshops reflected the goals of the program. In particular, the interaction with physicists during the second workshop (Gaspard, Smilansky) was very successful. In fact, Professor Gaspard of Brussels was, apart from the organizers, the most conscientious participant who attended all the talks, and contributed to questions and discussions. Perhaps one omission (pointed out by Smilansky) was the lack of a problem session: many problems and new directions came up during lectures and a formal set-up would have been helpful.

Other topics were also covered during the workshop: diffraction on manifolds with conic singularities, propagation of singularities for time dependent Schrödinger equations, inverse problems (notably for resonances), semi-classical approaches to non-linear Schrödinger equation, existence of absolutely continuous spectrum for Schrödinger operators with slowly decaying potentials.

Interaction with other programs. We would like to single out four instances of interesting interaction.

1. One of the most interesting talks of the second workshop was given by N. Burq on his work with P. Gérard and N. Tzvetzkov concerning applications of semi-classical methods to non-linear evolution equations. Both as far as the authors and the topics go this created an overlap with another recent program at ESI.

2. The talks of W. Müller and L. Ji on scattering on locally symmetric spaces were of interest to experts from the Mathematics Department of the University of Vienna (as well as to the 'Poisson structures' visitors to ESI), and lead to subsequent discussions and consultations.

3. S. Zelditch of Johns Hopkins who was a one month visitor of our program participated actively in the 'Poisson structures' program (which included his giving a talk in that workshop as well), and the 'Random Walks' program.

4. M. Zworski is organizing a semester in 'Semi-classical analysis' at MSRI in the spring of 2003. One of the goals of that program is to bring together mathematicians, physicists and chemists interested in semi-classics. Because of a certain overlap of topics we used the scattering program at ESI as an experimental ground for testing chances of such an interaction: our program had about 10% physics participation, while the MSRI we will aim for about 40%. The conclusion is that we can have a very interesting and fruitful interaction between mathematicians, physicists and chemists!

Focus on specific projects. In this section we will describe, from the personal perspective of the organizers, some projects which were strongly related to the program.

1. During the 'Spectral theory' program at ESI in the spring of 1998, V. Petkov and M. Zworski commenced their collaboration on the 'Breit-Wigner approximation'. That lead to publications of [S8], [S9], [S10]. Some of the results of [S8] were then generalized by J.-F. Bony [S1], and some of the results of [S10] by J.-F. Bony and J. Sjöstrand. The ultimate generalization to date was then achieved by V. Bruneau and V. Petkov [S7], who used also the related work of Bony [S2] and Sjöstrand [S12]. The topic of understanding Breit-Wigner approximation and the trace formulæ for resonances is far from exhausted and will lead to further work. Except for Bony (who was invited but could not attend) all the researchers mentioned here participated in the ESI program.

2. A. Vasy is involved in a project with A. Hassell and R.B. Melrose (both participating in the program) whose goal is to understand scattering for potentials which do not decay at infinity — see [S4]. Another group, with whom this direction of research originates [S5], consists of I. Herbst and E. Skibsted. They also participated in the program and their presence lead to an interesting and exciting exchange of views.

3. A. Vasy and X.-P. Wang worked together on a problem of regularity of the spectral shift function for the N-body problem and they made substantial progress [S13]. That worked was conducted at ESI and Université de Nantes (Wang's home institution): Vasy spent some time at Nantes, and Wang at ESI.

4. L. Ji and M. Zworski are continuing their work on scattering on locally symmetric spaces [S6] – the new project is party expository in nature and resulted from discussions at ESI. The idea is to make methods of [S6] more accessible by presenting them in a simpler setting.

Other projects were also the consequence of interaction during the meeting: Popov-Zelditch [S11], Popov-Stefanov (on lower bounds for the number of resonances, in progress), Wunsch (propagation of microlocal defect measures on manifolds with conic singularities, in progress), and more.

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[S4] A. Hassell, R.B. Melrose, and A. Vasy, *Spectral and scattering theory for symbolic potentials of order zero*, Séminaire E.D.P. 2000-2001, École Polytechnique.

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[S7] V. Bruneau and V. Petkov, *Meromorphic continuation of the spectral shift function*, ESI-preprint 1073 (2001).

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[S11] G. Popov and S. Zelditch, *KAM and converse quantum ergodicity*, preprint, 2001.

[S12] J. Sjöstrand, *Resonances for bottles and related trace formulæ*, Math. Nachr. **221** (2001), 95-149.

[S13] A. Vasy and X.-P. Wang, *Smoothness and high energy asymptotics of the spectral shift function in many-body scattering*, ESI-preprint 1048, 2001.

Invited scientists: Ivana Alexandrova, Vincent Bruneau, Nicolas Burq, Vladimir Buslaev, Monique Combescure, Predrag Cvitanović, Jan Derezinski, Mouez Dimassi, Shin-ichi Doi, Bruno Eckhardt, Julian Edward, Pierre Gaspard, Christian Gerard, Gian Michele Graf, Andrew Hassell, Ira Herbst, Michael

Hitrik, Mitsuru Ikawa, Hiroshi Isozaki, Victor Ivrii, Vojkan Jaksic, Wojciech Jaworski, Lizhen Ji, Alexander Kiselev, Evgeni Korotyaev, Ari Laptev, Gilles Lebeau, André Martinez, Anders Melin, Richard Melrose, Jacob Schach Moller, Werner Müller, Shu Nakamura, Laurence Nedelec, Jean-Philippe Nicolas, Leonid Parnovski, Vesselin Petkov, Georgi Popov, David William Pravica, Thierry Ramond, Didier Robert, Israel Michael Sigal, Johannes Sjöstrand, Erik Skibsted, Uzy Smilansky, Plamen Stefanov, Latchezar N. Stoyanov, Siu-Hung Tang, Gunther Uhlmann, Andras Vasy, Gueorgui Vodev, Lan Wang, Xue P. Wang, Jared Wunsch, Dimitri Yafaev, Kenji Yajima, Steve Zelditch, Maher Zerzeri, Maciej Zworski.

Random walks

Organizers: V. Kaimanovich, K. Schmidt and W. Wöss.

Total budget (including follow-up activities): ESI: ATS 1.091.155, external sources: ATS 647.750.

Dates: February 15 – July 15, 2001.

Preprints contributed: [1002], [1003], [1004], [1009], [1010], [1016], [1021], [1022], [1034], [1043], [1070], [1071], [1127], [1128], [1134], [1026], [1051], [1053], [1054], [1058], [1074], [1075], [1077], [1083], [1085], [1093], [1098], [1101], [1125] [1167], [1168], [1169], [1170], [1171], [1172], [1173], [1174].

Report on the program

The program was dedicated to various problems connected with stochastic processes on geometric and algebraic structures, with an emphasis on their interplay as well as on their interaction with Theoretical Physics. Some of the focal points were: *Probability on groups*, *Products of random matrices and simplicity of the Lyapunov spectrum*, *Boundary behaviour, harmonic functions and other potential theoretic aspects*, *Brownian motion on manifolds*, *Combinatorial and spectral properties of random walks on graphs* and *Random walks and diffusion on fractals*.

There were two separate main periods of activity: the first (in February/March) concentrated on **Random Walks and Statistical Physics**, and the second (in May/June/July) on **Random Walks and Geometry**. We also mention that there was a 'satellite conference' at the Technical University of Graz with the title **Fractals in Graz 2001**, June 4–9, 2001. The organizers of this satellite conference were Martin Barlow (University of British Columbia, Vancouver), Robert Strichartz (Cornell University, Ithaca), Peter Grabner (Technical University of Graz) and Wolfgang Wöss (Technical University of Graz). On the level of organization and funding, this workshop was disjoint from the ESI programme.

There will be a volume of Proceedings of the Random Walks Programme, published by de Gruyter. A separate proceedings volume will cover the workshop on Fractals in Graz.

First part: Random walks and statistical physics. As highlights of the first part we want to point out the lecture of Rob van den BERG on 'Hesitant coalescing random walks'. Also the lecture of Frank den HOLLANDER 'On the volume of the intersection of two Wiener sausages' not only was very clear and instructive, but he also was a very lively participant who contributed enormously to the success of the workshop by initiating many discussions.

Participants of first part of the program: Smail Alili (Cergy-Pontoise), Rob van den Berg (Amsterdam), Davide Cassi (Parma), Frank den Hollander (Eindhoven), Barry Hughes (Melbourne), Michael Keane (Eindhoven), Yuri Kifer (Jerusalem), Sergei Nechaev (Paris), Pal Revesz (Budapest/Vienna), Toshikazu Sunada (Sendai), Domokos Szasz (Budapest), Balint Toth (Budapest), Anatoli Vershik (St. Petersburg), Marton Balazs (Budapest), Maria S. Bernabei (Bonn), Daniela Bertacchi (Milano), Sara Brofferio (Paris), Leda Boussiakou (York), Pierfrancesco Buonsante (Parma), Raffaella Burioni (Parma), Marco Contedini (Parma), Dmitry Dolgopyat (Penn State), Sergei Fedotov (Manchester), Nina Gantert (Berlin), Thomas Gilbert (Rehovot), Ahmed Jellal (Trieste), Tadeusz Kosztolowicz (Kielce, Poland), Motoko Kotani (Sendai), Dmitry Kozakov (Moscow), Philippe Marchal (Lyon), Franz Merkl (Eindhoven), Michail Monastyrsky (Moscow), Francesca Nardi (Eindhoven), Igor Pak (Cambridge, Mass.), Alexander Rabodzei (Moscow), Frank Redig (Eindhoven), Sofia Regina (Parma), Silke Rolles (Eindhoven),

Alexander Soshnikov (Davis), Nina Stepanenko (Moscow), Andras Telcs (Budapset), Evgeny Verbitskiy (Eindhoven), Alessandro Vezzani (Parma), Martin Zerner (Haifa), Sergej Zhitomirskiy (Moscow), Fabio Zucca (Milano).

The first workshop.

Program:

Toshikazu SUNADA: Random walks applied to the geometry of crystal lattices.
Davide CASSI: Random walks and physical models on graphs - an introduction.
Thomas GILBERT: Entropy production and fractals.
Sergei FEDOTOV: Front propagation, random walks and large deviation theory.
Alessandro VEZZANI: The type problem on the average for random walks on graphs.
Rob van den BERG: Hesitant coalescing andom walks.
Motoko KOTANI: A central limit theorem for magnetic transition operators on a crystal lattice.
Domokos SZASZ: Statistical properties of the multidimensional Lorentz process.
Balinth TOTH: Self-repelling random walks and deposition models.
Silke ROLLES: Reinforced random walks.
Sergei NECHAEV: Conformal transforms and multifractality: geometry of locally non-uniform hyperbolic spaces.
Andras TELCS: Sub-Gaussian heat kernel estimates, and Harnack inequalities of andom walks on graphs.
Michail I. MONASTYRSKI: Statistics of knots and random walks on Hecke lattices.
Fabio ZUCCA: Equidistribution of random walks on spheres.
Smail ALILI: Discrete-time branching random walk and the voter model.
Daniela BERTACCHI: Classification on the average of random walks.
Vadim A. KAIMANOVICH: Random walks with random transition probabilities.
Wolfgang WÖSS: Periodic oscillations of transition probabilities on the Sierpinski graph.
Raffaella BURIONI: Random walks and geometrical universality on graphs.
Pal REVESZ: Local time of coalescing random walk.
Philippe MARCHAL: Loop-erased random walks and heaps of cycles.
Yuri KIFER: Dimension gap for continued fractions with random digits and related problems.
Frank REDIG: Entropy production for interacting random walks.
Evgeny VERBITSKIY: On the variational principle for the topological entropy of certain non-compact sets.
Francesca R. NARDI: Metastability for the Ising model with a parallel dynamics.
Igor PAK: Blind algorithms and Markov chains.
Dmitry DOLGOPYAT: Passive transport in random peridoic media.
Marton BALAZS: Structure of the shock in a new domain growth model.
Frank den HOLLANDER: On the volume of the intersection of two Wiener sausages.
Anatoli VERSHIK: Random walks on orbits of actions of groups (entropy and past).
Franz MERKL/Martin ZERNER: A zero-one law for planar random walks in random environment.
Barry HUGHES: Some stochastic problems for the new millennium.

Further seminars:

Michael KEANE: Random coin tossing.
Anatoli VERSHIK: Lebesgue measure in infinite dimensional space and properties of Levy's gamma processes.
Barry HUGHES: Continuous time random walks (At the Technical University of Graz)

Workshop on Fractals in Graz. Highlights were the talks of H. Furstenberg on 'Ergodic Theory and the Geometry of Fractals', and of R. I. Grigorchuk, 'From fractal groups to fractal sets'.

Program:

Th. COULHON (Cergy): Estimates for transition probabilities of random walks on infinite graphs.
M. BARLOW (Vancouver): Which values of the volume growth and anomalous diffusion exponents are possible?
C. SABOT: Spectral properties of fractal lattices and iteration of rational maps.
K. FALCONER (St. Andrews): Fractal aspects of random fields.
C. BANDT: Global and local symmetries of self-similar sets.
J.-M. REY: Properties of the dimension of a measure and the behaviour of correlation dimensions.
Y. XIAO: Renewal techniques for small ball probabilities of Brownian motion restrict to self-similar sets.
E. TEUFL: Hausdorff-dimension of overlapping self-similar sets and combinatorics on words.
P. SIRI: A stochastic algorithm to compute optimal probabilities in the chaos-game.
M. MENDÈS-FRANCE (Bordeaux): Infinite chains of strings and masses.
A. LASOTA (Katowice): Fractals, Multifunctions, and Markov Operators.
J. MYJAK: On dimensions of measures.
A. TEPLYAEV (Riverside): Dirichlet form analysis on the Sierpinski gasket.
B. KRÖN: Self-similar graphs and their spectrum.
C. WOLF: Fractal Julia sets in complex dynamics of C?
N. GLAZUNOV: Number theory, dynamical systems, and distribution of numerical sequences.

Z. BUCZOLICH: Hölder spectrum of typical monotone continuous functions.
R. WINKLER: Hausdorff dimensional results connected with the distribution of subsequences.
N. PATZSCHKE: Tangent measure distributions of self-conformal measures.
H. FURSTENBERG (Jerusalem): Ergodic Theory and the Geometry of Fractals.
R. I. GRIGORCHUK (Moscow): From fractal groups to fractal sets.
M. ZÄHLE: Riesz potentials and Besov spaces on fractals.
M. LAPIDUS (Riverside): Fractal Geometry and Number Theory.
J. THUSWALDNER: Neighbors of tiles in periodic tilings.
C. ESCRIBAÑO: A Combinatorial Method to Calculate Local Measure Dimension.
S. SASTRE: Hausdorff Dimension of Self-Similar Measures without the Open Set Condition.
W. STEINER: Digital Expansions and Rauzy Fractals.
T. KUMAGAI (Kyoto): Large Deviations and laws of the iterated logarithm for Brownian Motion on fractals.
S. KOCH: Construction of a Poisson boundary.
V. A. KAIMANOVICH: Fractals and hyperbolicity.
A. SOOS: Selfsimilar fractal functions using contraction method in probabilistic metric spaces.
A. PETRUSEL: Fixed points and fractals.
W. SLOMCZYNSKI: Entropy, dynamics, and fractals.
R. PEIRONE: Convergence of Discrete Dirichlet Forms to Continuous Dirichlet Forms on Fractals.
Popular talk for a general audience (in German): H.-O. PEITGEN: Ordnung im Chaos – Chaos in der Ordnung.
B. HAMBLY (Oxford): Branching processes and random recursive fractals.
A. TELCS: Random walks and a new type of Harnack inequalities.
K. HATTORI: Self-repelling Walk on the Sierpinski Gasket.
T. LUNDH: Martin boundary of a fractal domain.
V. METZ: Uniqueness of Laplacians on fractals and [0,1]d: orthogonal currents of reducible Dirichlet forms.
J. KIGAMI (Kyoto): Quasidistance and heat kernel asymptotics on self-similar sets.
U. FREIBERG: An Application of the Renewal Theorem to Measure Geometric Laplacians on Fractals.
V. E. ARKHINCHEEV: Microscopic models with anomalous diffusion and its generalizations.
D. GUIDO: Fractals in Noncommutative Geometry.
M. NDOYE: On the Black-Scholes model driven by mixed multifractal Brownian motion.
G. GOODMAN: How Statistical Mechanical Ideas Arise in a Problem of Computer Graphics.
A. GOETZ: Self similar structures in the dynamics of piecewise rotations

Second part: Random walks and geometry. Highlights were the lecture of Anna ERSCHLER (DYUBINA) on 'Random walks on amenable groups and harmonic functions on the universal cover of a Riemannian manifold' with surprising results on existence of bounded harmonic functions. The lecture of Stanislav SMIRNOV on 'Conformal invariance of critical percolation' presented prize winning and impressive results on percolation. Greg LAWLER on 'Conformal invariance and continuum limits of two-dimensional systems' presented a deep and impressive theory in collaboration with Oded Schramm and Wendelin Werner. Andrzej ZUK on 'Random walks and the Atyiah conjecture' gave the solution of a problem posed by Atyiah. Gregory MARGULIS on 'Recurrence properties of random walks on locally symmetric spaces'. Ilya GOLDSHEID on 'Lingering random walks in quasi-one-dimensional random environment' gave a very nice and clear talk about random walks in random environments.

Participants of the second part of the program. Martine Babillot (Orleans), Rob van den Berg (Amsterdam), Martin Barlow (Vancouver), Donald Cartwright (Sydney), Davide Cassi (Parma), Thierry Coulhon (Cergy), Persi Diaconis (Stanford), Steven Evans (Berkeley), Alex Furman (Chicago), Rostislav Grigorchuk (Moscow), Yves Guivarch (Rennes), David Handelman (Ottawa), Wojciech Jaworski (Ottawa), Michael Keane (Eindhoven), Gregory Lawler (Durham), Francois Ledrappier (Paris), Russ Lyons (Bloomington), Gregory Margulis (New Haven), Fabio Martinelli (Rome), Stansilav Molchanov (Charlotte), Pal Revesz (Vienna/Budapest), Ben-Zion Rubshtein (Beer-Sheva), Laurent Saloff-Coste (Ithaca), Jeff Steif (Goeteborg), Domokos Szasz (Budapest), George Willis (Newcastle, NSW), Georges Alexopoulos (Orsay), Valery Arkhincheev (Ulan-Ude), Laurent Bartholdi (Brasilia), Daniela Bertacchi (Graz), Sebasiten Blachere (Toulouse), Emmanuel Breuillard (New Haven), Sara Brofferio (Paris), Alexander Bufetov (Princeton), Anna Dioubina-Erschler (Tel Aviv), Galina Filipuk (Minsk), David Fisher (New Haven), Sergei Frolovichev (Moscow), Alexander Gamburd (Berkeley), Ilya Goldsheid (London), Eugene Gutkin (Santa Monica), Chris Hoffman (Seattle), Alessandra Iozzi (Zurich), Anders Karlsson (Zurich), Anatoly Katok (State College, PA), Tamer Khalil (Cairo), Anatoly N. Kochubei (Kiev), Mokhtar Konsowa (Jeddah, Saudi Arabia), Katarina Krupchik (Minsk), Michel Leprince (Rennes), Pierre Mathieu (Marseille), Michail Monastyrski (Moscow), Roman Muchnik (New Haven), Tatiana Nagnibeda (Stock-

holm), Volodia Nekrashevych (Kiev), Arnaldo Nogueira (Marseille), Sam Northshield (Plattsburgh), C. R. E. Raja (Bangalore), Jacqui Rammage (Newcastle, NSW), David Revelle (Ithaca), Riddhi Shah (Mumbai), Yehuda Shalom (Jerusalem), Nikita Sidorov (Manchester), Meir Smorodinsky (Tel Aviv), Rita Solomyak (Seattle), Varju Tamas (Budapest), Andras Telcs (Budapest), A. Uglanov (Yaroslavl), Tamas Varju (Budapest), John Velling (New York), Raphael Voituriez (Paris Orsay), Anton Zorich (Rennes), Fabio Zucca (Milano), Andrzeij Zuk (Lyon), Udo Baumgartner (Frankfurt), Abraham Boyarski (Montreal), Eliot Brenner (New Haven), Angeles Carmona (Barcelona), Tullio Ceccherini-Silberstein (Benevento), Christophe Cuny (Rennes), Moon Duchin (Chicago), Timothy R. Field (Malvern, UK), Wojciech Florek (Chicago), Pawel Gora (Montreal), Kenneth Hochberg (Ramat Gan, Israel), Irene Hueter (Gainesville), Inkang Kim (Seoul), Adam Koranyi (New York), Dimitry Kozakov (Moscow), Bernhard Kroen (Graz), Brenda MacGibbon (Montreal), Yuri Neretin (Moscow), Dimitri Petritis (Rennes), Christophe Pittet (Toulouse), Mark Policott (Manchester), Iris Reinbacher (Graz), Richard Sharp (Manchester), Karl-Theo Sturm (Bonn), Christiane Takacs (Linz), John Taylor (Montreal), Alain Valette (Neuchatel), Klaus Ziegler (Augsburg),

The second workshop.

Program:

Martin BARLOW: Which values of the volume growth and anomalous diffusion exponents are possible?
Anders KARLSSON: Multiplicative ergodic theory and Busemann functions.
Yves GUIVARC'H: Orbits of linear group actions, random walks on homogeneous spaces, and toral automorphisms.
Yuri NERETIN: Combinatorial analogue of the group of diffeomorphisms of the circle and Hilbert spaces associated with trees.
Roman MUCHNIK: Semigroup actions on T^n.
Domokos SZASZ: Recurrence of the planar Lorentz process by dynamical methods.
Sara BROFFERIO: How a centred random walk on the affine group goes to infinity.
Russell LYONS: Uniform spanning forests and the Geometry of random walks and groups.
Alexander BUFETOV: Markov operators and pointwise convergence of spherical averages for actions of free groups.
Shrikrishna G. DANI: Measures on groups, automorphisms and invariance.
Rita SOLOMYAK: Invariant measures for some equivalence relations.
Sam NORTHSHIELD: Cogrowth of arbitrary graphs.
Volodymir NEKRASHEVYCH: Limit spaces of self-similar group actions.
Jeff STEIF: Dynamical sensitivity of randomness.
John VELLING: Escape rates, growth rates and Hausdorff dimension - behaviour at infinity of hyperbolic manifolds.
Riddhi SHAH: Levy's measures and self-decomposable measures on Lie groups.
Raphael VOITURIEZ: Random walks on the braid group B_3 and magnetic translations in hyperbolic geometry.
Steve EVANS: Pinching and twisting Markov processes.
Pierre MATHIEU: Log Sobolev and spectral gap inequalities for the knapsack problem.
Thierry COULHON: Pointwise estimates for random walks on infinite graphs.
Inkang KIM: Affine actions and Margulis invariant.
Anna ERSCHLER (DYUBINA): Random walks on amenable groups and harmonic functions on the universal cover of a Riemannian manifold.
Donald I. CARTWRIGHT: Isotropic random walks on buildings.
Tullio CECCHERINI-SILBERSTEIN: Growth tightness of context-free languages.
Laurent BARTHOLDI: Random walks on surface groups, and cactus trees.
Tatiana NAGNIBEDA: Ergodic properties of boundary actions.
Rostislav I. GRIGORCHUK: On spectra of Markov operators on groups and graphs.
Stanislav SMIRNOV: Conformal invariance of critical percolation.
Greg LAWLER: Conformal invariance and continuum limits of two-dimensional systems.
Chris HOFFMAN: Random walk on percolations clusters.
Mark POLLICOTT: Ergodicity of frame flows and their stable foliations.
Ben-Zion RUBSHTEIN: On a class of one-sided Markov shifts.
Wojciech JAWORSKI: Boundaries of random walks and SAT actions of locally compact groups.
Andrzej ZUK: Random walks and the Atyiah conjecture.
Richard SHARP: A local limit theorem for closed geodesics and homology.
Francois LEDRAPPIER: Ergodic properties of some linear actions.
David FISHER: Local rigidity of group actions on homogeneous manifolds.
Tim FIELD: Stochastic Hamilton-Jacobi theory on manifolds - the emergence of wave-functions.
Pawel GÓRA: Absolutely continuous invariant measures for random maps with position dependent probabilities.

Bernhard KRÖN: Green functions and asymptotics of transition probabilities on self-similar graphs.
Gregory MARGULIS: Recurrence properties of random walks on locally symmetric spaces.
Ilya GOLDSHEID: Lingering random walks in quasi-one-dimensional random environment.
Franz LEHNER: On the computation of spectra on free product groups.
Christophe PITTET: On an inequality of Varopoulos for finitely generated groups and the question of its optimality.
Andras TELCS: On an almost new isoperimetric inequality.
Dimitri PETRITIS: Random walks on randomly oriented lattices.
Fabio MARTINELLI: Asymmetric simple exclusion and interfaces of the quantum XXZ model.
Irene HUETER: Mean square displacement of self-avoiding walk in all dimensions.
Alex FURMAN: Entropy and cocycle growth along random walks.
Alex ESKIN: Uniform exponential growth for linear groups.
Anton ZORICH: Geometry and dynamics of flat surfaces.
Arnaldo NOGUEIRA: Ergodic properties of the Euclidean algorithms.
Nikita SIDOROV: Unique beta-representations of real numbers and dynamics.
Angeles CARMONA: Boundary values on networks: some applications to random walks.
David REVELLE: Rate of escape of random walks on groups.
Laurent SALOFF-COSTE: Lower bound in total variation for random walks on finite groups.
Georges ALEXOPOULOS: Random walks on nilpotent groups.
Sebastien BLACHERE: Cut times for random walks on groups of polynomial growth.
Alexander GAMBURD: Expander graphs, random matrices and quantum chaos.
Stanislav MOLCHANOV: Random walks on finite and compact groups and testing of RNG.
Marc BURGER: Bounded cohomology and rigidity theory.
Alessandra IOZZI: De Rham cohomology of amenable foliations.
George WILLIS: Totally disconnected locally compact groups.
Christiane TAKACS: Strong law of large numbers for branching Markov chains.
Anatoly KOCHUBEI: Stochastic processes over non-Archimedian fields.
Valery ARKHINCHEEV: Fractal diffusion equations: microscopic models with anomalous diffusion.
Eugene GUTKIN: Mathematics of billiards.
Anatoly KATOK: Are random walks any good for classical dynamical systems?

Mathematical Cosmology

Organizers: P.C. Aichelburg, G.F.R. Ellis and V. Moncrief.

Total budget (including follow-up activities): ESI: ATS 468.853, external sources: ATS 9.000.

Dates: June 15 - August 15, 2001.

Preprints contributed: [1057], [1117], [1119], [1120], [1122], [1123] [1136], [1137], [1140], [1141], [1156]..

Report on the program by P. Aichelburg

The program was aimed to the development and application of mathematical methods for the study of anisotropic and inhomogeneous cosmological models with a view towards understanding their global structure and evolution and towards uncovering limitations in the idealized homogeneous models.

Long-times-existence and asymptotic behavior. Among the most challenging mathematical problems in classical general relativity are those related to the long-time-existence and asymptotic behavior of inhomogeneous solutions to Einstein's equations. During the ESI program higher order energy estimates were used to analyze a large family of Ricci flat spacetimes of expanding cosmological models for proving global existence and asymptotic behavior(Lars Anderson, Y. Choquet and V. Moncrief). The asymptotic behavior was numerically partially verified in the expanding direction for Gowdy metrics on the 3-torus (B.Berger).

Perhaps even more challenging are questions about asymptotic behavior in the direction of collapse since these must confront the complexity of spacetime singularities. Recent results emerging from these numerical studies have provided strong evidence for the conjectures that velocity-dominated and, more generally Belinsky–Lifschitz–Khalatnikov behavior should occur in certain classes of inhomogeneous Einstein spacetimes. The already successful proven idea to apply the Fuchsian method to study spacetime singularities was further developed. (J.Isenberg, V. Moncrief and A. Rendall) Work was completed on the Fuchsian methods applied to velocity dominated singularities in U(1) symmetric vacuum spacetimes.

The idea that certain homogeneous, or at least highly symmetric, cosmological solutions may be 'attractors' in the full phase space for Einstein's equations is a key motivation for studying cosmology in a setting of dynamical systems. With the help of new techniques such as the use of expansion normalized frame variables and the Ellis–van Elst formulation of the field equations as a hyperbolic system some of the issues addressed were: Does the asymptotic self-similarity observed in certain families of cosmological solutions have a deeper significance – why is self-similarity a common feature in a number of the known 'attractors'? What are the limits to conclusions drawn from purely homogeneous models? (G. Ellis, H.v. Elst, C. Uggla, J. Wainwright) The program also provided an opportunity for confronting the Hamiltonian with the orthonormal frame approach. A number of collaborations were initiated.

Critical Phenomena in gravitational collapse. Several studies during the last few years have uncovered critical behavior in the (spherically symmetric) gravitational collapse of a variety of matter field and perfect fluid systems which is analogous to that in statistical mechanics. Following some early work of Christodoulou it was shown numerically by Choptuik that there exists a threshold for the initial data leading to black hole formation by a massless scalar field which exhibits both scaling and universality. This threshold is characterized by a selfsimilar solution of the field equations and an associated co-dimension one attractor (i.e., one having a single unstable mode) in the phase space of initial data for the system. This critical behavior has now been observed for several types of gravitating matter sources and, in the case of axial symmetry, for the pure gravitational field itself. While the examples studied so far represent isolated systems in an asymptotically flat context, the basic phenomenon is a quasi-local one for which the precise asymptotic conditions are irrelevant. Thus this critical behavior will be equally significant in cosmology at the onset of black hole formation and perhaps also for the occurrence of stable stellar or geon-like configurations. Furthermore the selfsimilar critical solutions that signal the threshold of collapse are known to have naked singularities (i.e., regions of unbounded spacetime curvature that are not hidden behind event horizons). This existence represents a fundamental limitation to the use of energy methods to prove long-time-existence theorems for the case of sufficiently large initial data. When singular solutions exist (and when their singular regions are not safely hidden inside black holes) then the energy methods must break down or at least require a significant refinement. During the program substantial progress was made in proving existence of continues selfsimilar solutions for certain wave maps coupled to gravity. (P. Bizon and A. Wasserman) Moreover, work on the numerical/analytical studies of a new transition from continues to discrete self-similar behavior was reported (P.C. Aichelburg).

Topological aspects of cosmological models. There is an intimate connection between the dynamics of general relativity and the topology of the manifold upon which Einstein's equations are formulated. For the cases of most physical interest (globally hyperbolic, time-orientable spacetimes) the 4-manifold is a product of the form $M \times \mathbb{R}$ (roughly space $\times$ time) with the interesting topology thus confined to the spatial factor M. For the important special case of a 'closed' universe M is compact and the possible choices for M are the objective of the 3-manifold classification program. For many such 3-manifolds (those of the so-called negative Yamabe type) it is well-known that an expanding universe can never develop a maximal hypersurface and begin to collapse. Quite recently however a direct connection has been found for such manifolds between the infimum of the reduced (Arnowitt–Deser–Misner) Hamiltonian for Einstein's equations H_{ADM} and the topological invariant called the σ-constant of M (which Michael Anderson has used extensively in his reformulation of the Thurston 3-manifold classification program). During the program the above raised issues were discussed.(M. Anderson, A. Fischer and V. Moncrief). Implications of non-trivial topologies of the universe for observation were analyzed (R. Tavakol).

Seminars given during the program.

Vince Moncrief: Einstein Spaces as Attractors for the Einstein Equations.
Henk van Elst: Scale Invariant Dynamics for G-2 Cosmology.
G.F.R. Ellis: Inflationary Dynamics and Horizons.
Alan Rendall: Fuchsian Equations and Spacetime Singularities.
Peter C. Aichelburg: Episodic CSS in Critical Collapse.
Alan Rendall: Fuchsian Equations and Spacetime Singularities.
Reza Tavakol: Aspects of approximately flat Cosmologies.
Lars Anderson: BKL and Gowdy Cosmologies.

Dieter Brill: Cosmology in 2+1 gravity.
Michael Anderson: Relations between vacuum evolution of space-times and geometrization of 3-manifolds.
Arthur Fischer: The Reduction of Einstein's Equations in Higher Dimensions.
István Rácz: On rigidity of cosmological spacetimes with a compact Cauchy horizon.
Hans Ringström: Gowdy vacuum space-times - detailed asymptotics for an open set of initial data.
Beverly Berger: Exploring Mathematical Cosmology with Computer Simulations.

Participants. Peter C. Aichelburg, Lars Andersson, Michael Anderson, Beverly Berger, Piotr Bizon, Dieter Brill, Marco Bruni, Yvonne Choquet-Bruhat, George F. R. Ellis, Arthur Fischer, Helmut Friedrich, Jim Isenberg, Roy Maartens, Vincent Moncrief, Istvan Racz, Alan Rendall, Wolfgang Rindler, Hans RingstrÖm, Mattias Sandberg, Masayuki Tanimoto, Reza Tavakol, Claes Uggla, Henk Van Elst, John Wainwright, Arthur Wasserman, Marsha Weaver.

Mathematical Aspects of String Theory

Organizers: M. Blau, F. O'Farril, A. Schwarz, H. Urbantke.

Total budget (including follow-up activities): ESI: ATS 821.000, external sources: ATS .

Dates: September 3 to November 16, 2001.

Preprints contributed: [1087], [1090], [1096], [1099], [1100], [1102], [1103], [1104], [1106], 2002: [1116], [1118], [1126], [1129], [1162], [1193], [1194], [1195], [1220].

Report on the program by M. Blau

The purpose of this meeting was to bring together mathematicians and physicists working on a variety of mathematical aspects of string theory and string-inspired mathematics. The aim was to bridge the language gap that occasionally exists even between mathematical physicists and mathematicians, and thus to create a stimulating environment allowing for a fruitful exchange of ideas and cross-disciplinary discussions and collaborations.

This meeting was attended by approximately sixty invited participants, mostly young researchers working in (Eastern and Western) Europe or the United States. As a consequence of the events of September 11th, however, there were a significant number of short-term cancellations by distinguished colleagues from the United States.

In addition, the meeting had a loyal following among members of the scientific community in Vienna who welcomed the opportunity to receive first-hand accounts of the exciting developments that have occurred in string theory in recent years and regularly came to our seminars.

String theory, even when limited to its more mathematical aspects, is a vast field. It was thus mandatory to provide some kind of subdivision of the 11-week programme without, however, narrowing down the subjects too much, as this would have been contrary to the spirit of the programme whose aim it was, after all, to encourage the exchange of cross-disciplinary information. In the end we settled for a rough division into three parts, namely

1. Non-Commutative Geometry and Non-Commutative Field Theory (Week 1-4)
2. Mirror Symmetry, D-branes and Supersymmetric Gauge Theories (Week 5-7)
3. Differential Geometry and Supergravity Branes (Week 8-11)

These three headings cover the main areas of current research on string theory with the exception of the more phenomenological issue of physics of large extra dimensions and model building.

The backbone of the programme were regular series of two or three introductory lectures delivered by leading researchers in the field, e.g.

- by Connes, Nekrasov and Schwarz on non-commutative geometry and non-commutative field theory,

- by Schweigert on boundary conformal field theory,
- by Tatar on geometric transitions and strong coupling results in field theory,
- by Klemm, Kapustin and Ruan on on various aspects of mirror symmetry,
- and by de Wit, Nicolai and Bandons on supergravity and supergeometry.

These lectures were accompanied by a variety of one-hour seminars on related topics, providing an at times relaxed and at times somewhat more intense schedule with on average seven lectures a week, amounting to a total of seventy-seven seminars in eleven weeks, divided among the approximately sixty participants of the programme.

Outside these lectures, the ESI provided a perfect environment for everything ranging from informal discussions and mini-tutorials to intense calculations and collaborations. At all times of the day, and frequently also far into the night, one would see groups of people gathered in front of one of the numerous blackboards, either in the corridor or in the common room, discussing, working, calculating.

We believe that, by this token alone, the meeting has to be considered a success, as it was precisely this kind of atmosphere and activity that the organizers had hoped to create. This impression is confirmed by the (exclusively positive) feedback we have received from the participants of the programme.

Our colleagues were also full of praise for the administration of the ESI, and we would like to take this opportunity to thank Maria Windhager, Eva Kissler and Ursula Sagmeister for their unfailing support, helpfulness and kindness throughout the programme. Credit for the success of our programme should also go to them.

Invited scientists. Mohab Abou-Zeid, Christoph Adam, Paolo Aschieri, José Azcárraga, Igor Bandos, Helga Baum, Florin Belgun, Matthias Blau, Udo Bruzzo, David Calderbank, Alain Connes, Lorenzo Cornalba, Ludwik Dabrowski, Chand Devchand, Bernard De Wit, Bergfinnur Durhuus, José M. Figueroa-O'Farrill, Bartomeu Fiol, Jürgen Fuchs, Cesar Gomez, Rafael Hernández, Christopher Hull, Daniel Huybrechts, Ines Kath, Vladimir Kazakov, Michael Keane, Bumsig Kim, Nakwoo Kim, Yoshihisa Kitazawa, Albrecht Klemm, Anatoly Konechny, Giovanni Landi, Felipe Leitner, Fedele Lizzi, Ruben Minasian, Kumar Narain, M.S. Narasimhan, Sergei Natanzon, Nikita Nekrasov, Hermann Nicolai, Jacek Pawelczyk, Alexander Polishchuk, Leonid Positselski, Andreas Recknagel, Alexei Rosly, Wei-Dong Ruan, Henning Samtleben, Emanuel Scheidegger, Volker Schomerus, Albert Schwarz, Christoph Schweigert, Uwe Semmelmann, Harald Skarke, Simón Joan Soler, William Spence, Radu Livili Tatar, Daniel Waldram.

Nonlinear Schrödinger and quantum-Boltzmann equations

Organizers: P. Gérard, P.A. Markowich, N.J. Mauser, G. Papanicolaou.

Total budget (including follow-up activities): ESI: ATS 947.000, external sources: ATS 57.000.

Dates: Fall 2001 (originally requested: Spring 2001).

Preprints contributed: none.

Report on the program by N. Mauser

The programme has been very successful, both for organizing 4 workshops, 2 summer and/or winter-schools and for scientific work in small groups. A lot of scientific interaction of the ESI invitees among them and with Austrian groups took place. In particular PhD students, partly from the new Austrian PhD programme on 'differential equations' interacted well with the ESI funded visitors. Hence an important activity of this programme were the 2 'schools' on NLS, one in February, one in July-August. These high level courses were attended by students from all over the world, thanks to a cofinancing from the START project of NJM for travel and from the Vienna PhD Programme (Wissenschaftskolleg) 'Differential equations' (speaker C. Schmeiser) for funding the lecturers (see below for a list). The workshops in fall were both high level conferences and a platform for 'working groups' on particular topics and publications.

However, there has been a certain unforeseen difficulty since most activities took place after Sep. 11 and the majority of North American colleagues decided on short hand notice not to attend the 3 workshops afterwards. Also, GP as one of the organizers, could not come to Vienna in fall.

In fall, this ESI programme coincided with a thematically close 'special trimester' at the IHP in Paris, organized by F. Golse (ENS Ulm). In the course of a close collaboration, there was a 'twin colloquium' Paris-Vienna in honor of Claude Bardos, with the first part at the IHP/DMA in September, the second part in October at the ESI/WPI (Wolfgang Pauli Institute).

Budget and co-financing. Direct additional funding has been provided by the Wittgenstein prize of PAM, the European TMR network 'Asymptotic Methods in Kinetic Theory', and - massively - by the START prize of NJM who cofinanced travel of many participants of this programme.

Scientific highlights of the programme. The programme not only contributed to scientific breakthroughs of state-of-the-art problems, but triggered work on new topics with new methods that arose from the discussions in the working groups at the ESI. As examples we mention the use of the 'modulated energy method' of Y. Brenier to limits from Vlasov-Maxwell and Schrödinger-Poisson to incompressible Euler and e-MHD equations in collaboration with NJM and M. Puel who was in the group of NJM as a European TMR network post doc at that time (e.g. [BrMPu2]). Another example is the work of NJM together with P. Bechouche and S. Selberg on the nonrelativistic limit of the Klein-Gordon Maxwell system towards the Schrödinger-Poisson system, a breakthrough based on Selbergs capability to 'turn the Klainerman-Macheddon machinery' [BeMSe1]. Also the work [ZZM1] of NJM with Ping Zhang from the Chinese Academy of Science and Yuxi Zheng from Bloomington (now Pittsburgh) on the classical limit from Schrödinger-Poisson to Vlasov-Poisson for the pure state case attracted a lot of attention. This 1-d result based on an improvement of the Zheng-Majda (diPerna) result on measure valued solutions of Vlasov-Poisson is the first work to get rid of the particular 'mixed state assumption' that also P.L. Lions and T. Paul had to use in their famous 93 paper. Another real breakthrough was given in a series of papers of the frequent ESI visitors F. Golse and C. Bardos together with NJM on the derivation of the Schrödinger-Poisson system from the linear N particle Schrödinger equation with Coulomb interaction. The final step was done in collaboration with L. Erdös and H.T. Yau [BEGMY] who delivered the crucial estimates on compressed trace norms for proving uniqueness of the limit hierarchy. In follow up work the case of fermions, i.e. antisymmetrized initial data is dealt with [BGGM2] - this work is done together with A. Gottlieb and aroused interest, e.g. in the group of C. LeBris at the ENPC and people at the French Atomic Energy Commission. A continuation of this promising collaboration as a follow up workshop of this ESI programme is foreseen in March.

As another example we mention that the collaboration of PAM with Shi Jin from Georgia Tech and Singapore based Weizhu Bao together with the Innsbruck team around P. Zoller on numerics of NLS was enhanced by this ESI programme and resulted in one of the best simulation codes for 3-d simulation of Bose Einstein Condensates [BMS1], [BMS2], [BJM1]. An adapted version of this code has proven to be very valuable for simulations of the Schrödinger-Poisson-Xα equation [BMS1] as the simplest DFT model including the exchange interaction due to the Pauli principle. Together with S. Kamvissis this numerical method is currently used also for simulations of the 'classical' cubic NLS, where the 'integrable system approach' is pushed to 2+1 dimensional problems, where numerical simulations give valuable insight for the analysis. It is highly desirable to continue these collaborations.

Also the invitations of PG in this ESI programme have resulted in several new research programmes - as a result we mention the collaboration with N, Tzvetkow and N. Burq [BGZ1], [BGZ2], [BGZ3].

The invitation of A. Komech in the course of this ESI programme has not only produced high level publications but also triggered the build-up of a strong group in Vienna working on the asymptotic stability of solitons in a quantum relativistic context, like Klein-Gordon coupled to a classical particle. As a result of this ESI programme Prof. Komech will come to Vienna as visiting professor, cofunded by NJM. However, it his highly desirable to invite also his PostDoc Tatiana Dudnikova for the month of March as a 'follow up' event of this ESI programme.

A particular highlight was the summer school on NLS where among others Vienna born Wilhelm Schlag (now Caltech) gave his Princeton lectures on 'harmonic analysis and PDEs' - attended by about

20 students from all the world, mainly from the groups at the WPI and French students from places like the ENS.

Selected publications. In the sequel we give a short list of some particular important publications produced in direct collaboration of researchers participating in this ESI programme.

[BEGMY] C. Bardos, L. Erdös, F. Golse, N.J. Mauser, H.-T. Yau, Derivation of the Schrödinger-Poisson equation from the quantum N-particle Coulomb problem, to appear in C.R.A.S. (2002).

[BrMPu2] Y. Brenier, N.J. Mauser, M. Puel Incompressible Euler and e-MHD as scaling limits of the Vlasov-Maxwell system, submitted to Comm. Math. Phys. (2002).

[BaMSt1] W. Bao, N.J. Mauser, H.P. Stimming The Schrödinger-Poisson-α equation, submitted to Chaos (2002).

[BeMSe1] P. Bechouche, N.J. Mauser, S. Selberg Nonrelativistic limit of Klein-Gordon-Maxwell to Schrödinger-Poisson, preprint (2002).

[BaJiM1] W. Bao, Shi Jin, P.A. Markowich Time-splitting spectral approximations for the Schrödinger equation in the semiclassical regime, to appear in J. Comp. Phys. (2002).

[BaJiM2] W. Bao, Shi Jin, P.A. Markowich Numerical Study of time-splitting spectral Discretization of nonlinear Schroedinger Equations in the Semiclassical Regimes, submitted (2001).

[BaJaM1] W.Bao, D.Jaksch, P.A. Markowich Numerical Solution of the Gross-Pitaevskii Equation for Bose-Einstein Condensation, manuscript (2002).

[BGT1] N. Burq, P. Gérard et N. Tzvetkov Strichartz inequalities and the nonlinear Schrödinger equation on compact manifolds, Preprint Orsay (2001).

[BGT2] N. Burq, P. Gérard et N. Tzvetkov An instability property of the nonlinear Schrödinger equation on the sphere, Preprint Orsay (2001).

[BGT3] N. Burq, P. Gérard et N. Tzvetkov Two singular dynamics of the nonlinear Schrödinger equation on a plane domain, in preparation (2002).

[PoVa] F. Poupaud and A.Vasseur Classical and Quantum Transport in Random Media, submitted (2002).

[ZZM] P. Zhang, Y. Zheng and N.J. Mauser Classical limit from Schrödinger-Poisson to Vlasov-Poisson equations for general initial data including the pure state case, in 1-d, to appear in Comm. Pure and Appl. Math. (2002

Special events in the course of the programme. In the sequel give an overview information - for details of the activities, including the full list of participants (with or without ESI funding) please see the web-page of the programme. By coincidence, during the first winter school, there was a nice interaction with participants of the parallel workshop of the 'Nonequilibrium Statistical Mechanics' programme (e.g. with H. Spohn, S. Kuksin).

- **Winter School on NLS**, Feb. 5th - 16th, 2001, organized by PG and NJM.
- **Workshop on Nonlinear Dispersive Equations**, July 17-24, 2001, organized by PG and NJM.
- **Summer School on NLS**, July 24 - Aug 25, 2001, organized by NJM.
- **Colloquium on Hydrodynamical Limits: Results and Perspectives**, October 19-24, 2001, organized by NJM.
- **Workshop on Semiclassical Limits: WKB methods vs Wigner Transform Methods**, Nov. 20-26, 2001, organized by NJM, PG and PAM.
- **Workshop on (Asymptotic) Analysis of the Dirac-Maxwell System**, Dec. 10-14, 2001, organized by NJM, G. Rein and S. Selberg.

Invited scientists. Ben Abdallah, Thomas Alazard, Hakan Andréasson, Christophe Antonini, Kazuo Aoki, Anton Arnold, Weizhu Bao, Claude Bardos, Abdelghani Bellouquid, Jean-David Benamou, Poitr Biler, Xavier Blanc, Yann Brenier, Nicolas Burq, Timothy Cale, Rémi Carles, Jose A. Carrillo, Jean-Marc Delort, Juan Carlos De Los Reyes, Bernard Ducomet, Tatiana Dudnikova, Klemens Fellner, Clotilde Fermanian, Ester Gabetta, Davide Gabrielli, Isabelle Gallagher, Clément Gallo, Patrick Gérard, Omar Gil, Matthias K. Gobbert, Michael Goldshtein, Francois Golse, Alexandre Gorboulski, Alex Gottlieb, Thierry

Goudon, Jean-Claude Guillot, Myo Thein Gyi, Emmanuel Jabin, Shi Jin, Qiangchang Ju, Spyros Kamvissis, Grzegorz Karch, Sahbi Keraani, Michael Kiessling, Alexander Komech, Elena Kopylova, Frédéric Lagoutiére, Celine Laurent, Hailiang Li, Yuri Lvov, Alex Mahalov, Josef Malek, Nader Masmoudi, Frank Merle, Luc Miller, Peter D. Miller, Simon Moulin, Christophe Pallard, Mathieu Pilot, Fabrice Planchon, Raphael Poncet, Frédéric Poupaud, Jagdish Rai, Suranjana Rai, Pierre Raphael, Michel Rascle, Mukhaya Rasulova, Gerhard Rein, Michael Renardy, Yuriko Renardy, Alan Rendall, Leonid Ryzhik, Wilhelm Schlag, Sigmund Selberg, Walter A. Strauss, Shaoqiang Tang, Giuseppe Toscani, Nikolay Tzvetkov, Seiji Ukai, Muthusamy Vanninathan, Alexis Vasseur, Björn Walther, Gershon Wolansky, Jorge Passamani Zubelli.

Workshops organized outside the main programs

Winter school in geometry and physics

January 13–20, 2001, Srní, Czech Republic, with a contribution by ESI of ATS 10.000. The proceedings will be published in Suppl. Rend. Circ. Mat. Palermo, II. Ser.

75th anniversay of the Schrödinger equation.

A series of lectures organized by W. Reiter and J. Yngvason.

The program: March 28. T. Hänsch (MPI Garching): Atomoptik und Materiewellen.
May 9. P. Zoller (Uni Innsbruck): Engineering entanglement.
May 10. J. Yngvason (Uni Wien): The roots of the Schrödinger equation.
May 10. G.M. Graf (ETH Zürich): Classical action and Quantum scattering.
May 10. J. Burgdörfer (TU Wien): What do Schrödinger waves know about Chaos?

Poisson geometry

June 13 – 22, 2002 Organized by A. Alexeev and P. Michor.

Program: A. Gorski (Moscow): Duality and integrability.
J.-Cl. Hausmann (Geneva): Genetics of the Poisson reduction of products of R^3's.
Steve Zelditch (Johns Hopkins): Moment maps, Newton polytopes and zeros of polynomials.
A. Rosly (Moscow): Polar Homology.
V. Roubtsov (Angers): Double elliptic 'elegant' integrable system.
Yuri Neretin (ITEP, Moscow and ESI, Vienna): Dymplectic category and second quantization.
Peter Michor (Vienna): Calogero-Moser systems with spin via symplectic reduction.
P. Xu (Penn State): Calogero-Moser systems with spin via symplectic reduction.
V. Ginzburg (UC Santa-Cruz): Grothendieck Groups of Poisson Vector Bundles.
B Dubrovin (SISSA): Normal forms of integrable PDEs, tau-functions and Gromov-Witten invariants.
B. Kostant (M.I.T): The Weyl algebra and the structure of all Lie superalgebras of Riemannian type.
M. SEMENOV-TIAN-SHANSKY (Dijon): Q-deformed Toda lattice, the modular double, and representations of $U_q(sl(2,\mathbb{R}))$.
V. Fock (Moscow): Cosh-Gordon equation and quasi-Fuchsian groups.
B. Kostant (M.I.T): The character variety in T*G, geometric quantization, symplectic reduction and the Harish-Chandra character formula.
D. Lebedev (Moscow): Wave functions of the q-deformed Toda lattice.
O. Kravchenko (Lyon): Structures up-to homotopy and deformations of Hopf algebras.
V. Ginzburg (UC Santa Cruz): Morita category in Poisson Geometry.
Yuri Neretin (ESI): Combinatorial analogue of the group of diffeomorphisms of the circle and Hilbert spaces associated with trees.
Yves Guivarch (Univ.): Orbits of linear group actions, random walks on homogeneous spaces, and toral automorphisms.
A. Weinstein (UC Berkeley): Courant algebroids.
K Gawedzki (I.H.E.S and ENS, Lyon): Wess-Zumino-Witten and Chern-Simons theories with boundary.
P Boalch (SISSA): Stokes matrices and Poisson Lie groups.
E. Meinrenken (Toronto): Poisson-Lie groups and the hyperbolic Duflo map.
P. Severa (IHES): Courant algebroids, homotopy and variational problems.
P. Xu (Penn State): Stokes matrices and Poisson Lie groups.
T. Strobl (Jena): Poisson Sigma Models with 3-Form.
D. Roytenberg (Penn State): On the structure of symplectic supermanifolds and Courant algebroids.
J. Huebschmann (Lille): Lie-Rinehart triples, quasi-Gerstenhaber and quasi-Batalin-Vilkovisky algebras.

P. Bressler (Angers): Polarized deformation quantization.
T. Ratiu (Lausanne): The optimal momentum map.

Participants. Philip Boalch, Paul Bressler, Boris Dubrovin, Vladimir Fock, Victor Ginzburg, Alexander Gorski, Jean-Claude Hausmann, Johannes Huebschmann, Bertram Kostant, Olga Kravchenko, Dimitriy Lebedev, Jiang-Hua Lu, Eckhard Meinrenken, Tudor S. Ratiu, Alexei Rosly, Vladimir Roubtsov, Dmitry Roytenberg, Michael Semenov-Tian-Shansky, Thomas Strobl, Aexandre Tchervov, Pavol Ševera, Alan Weinstein.

Visitors outside the main programs

Visitors to ESI not associated with any of the main programs and workshops contributed the preprints [1049], [1056], [1089], [1135], [1011], [1046], [1108], [1124], [1130], [986], [1094], [1111], [1112], [1131], [1132], [1030], [1050], [1086], [1107], [979], [1078], [990], [1027], [1029], [1042], [1055], [1061], [1082], [1092], [1097], [1109], [1121], [1021], [1022], [1034], [1043], [1070], [1071], [1127], [1128], [1134], [980], [982], [996], [997], [1027], [1037], [1038], [1046], [1082], [1063], [1064], [1066], [1076], [1081], [1088], [1105], [1109], [1110], [1114], [1129], [989], [1084], [1095], [992], [1017], [1018], [1033], [1037], [1038], [1039], [1059], [1069], [1072], [1097]. This lists includes preprints contributed by the Senior Research Fellows and their collaborators.

ESI spent ATS 1.008.000, with external contributions amounting to ATS 475.500. These figures do not include the invitations issued by the Senior Research Fellows which are budgeted separately.

Guests of A. Cap. Rod Gover, Jan Slovak.

Guests of P. Michor. Ilka Agricola, Leonid Friedlander, Thomas Friedrich, Franz W. Kamber, Alexander Klyachko, Bertram Kostant, Dmitriy Kozakov, Mark V. Losik, Nikolai Nadirashvilli, Giovanni Sparano, Gaetano Vilasi, Ernest Vinberg, Patrizia Vitale, Cornelia Vizman, Mariusz Wodzicki.

Guests of K. Schmidt. Siddhartha Bhattacharya, Madabusi Santanam Raghunathan, Wolfgang Schmidt.

Guests of W. Thirring. Nevena Petrova Ilieva-Litova, Dmitri Petrina.

Guests of J. Yngvason. Alexei A. Abrikosov, Hans-Jürgen Borchers, Detlev Buchholz, László Erdős, Soren Fournaisalekseev, Krzysztof Gawedzki, José M. Gracia-Bondia, Gian Michele Graf, Piotr Hajac, Theodor W. Hänsch, Bernard Helffer, Bernard S. Kay, Ari Laptev, Elliott Lieb, John Roberts, Manfred Salmhofer, Florian Scheck, Armin Uhlmann, Michiel van den Berg, Dmitri Vassilevich, Heribert Zenk.

Guests of S.G. Dani. Robinson Edward Raja, Arnaldo Nogueira.

Guests of I. Todorov. David Broadhurst, Bojko Bakalov, Dirk Kreimer, Dimitri Leites, Yassen Stanev, Nikolay Mitov Nikolov.

The year 2002

General remarks

Management of the Institute

Honorary President: Walter Thirring
President: Jakob Yngvason
Directors: Peter Michor and Klaus Schmidt
Administration: Maria Windhager, Eva Kissler, Ursula Sagmeister
Computers: Andreas Čap, Gerald Teschl, Hermann Schichl

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Viktor Kac (MIT)
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Harald Niederreiter (Singapore)

Senior Research Fellows

Shrikrishna G. Dani (March 22 – August 31)
Yurii A. Neretin (January 1 – February 28)
Arkadi Onishchik (October 1 – December 20)
Ivan Todorov (February 1 – May 31 and November 1 – December 31)
Anatoli Vershik (October 16 – December 15)

Advanced Graduate Lectures Series

In 2002, ESI started the *Senior Research Fellows Advanced Graduate Lectures Series* with financial support by the University of Vienna. The first two courses in this series were given by Arkadi Onishchik and Anatoli Vershik.

Arkadi Onishchik: Real Forms and Representations, on Tuesdays, 15.30-17.00, ESI Lecture Hall, October 8, 2002 - December 20, 2002.

Contents:

1. Complexification and real forms of Lie algebras. Real structures (antiinvolutions). Conjugate complex Lie algebras. The cases of semisimple and simple Lie algebras. (Short review)
2. Complex semisimple Lie algebras. Root space decomposition, simple roots, the Weyl group, Weyl chambers. The normal and the compact real forms. The Weyl involution. (Short review)
3. Hermitian geometry in a complex semisimple Lie algebra. Correspondence between real structures and involutive automorphisms.

4. Automorphisms of complex semisimple Lie algebras. The semidirect decomposition of the automorphism group. The canonical presentation of an involutive automorphism. The principal 3-dimensional subalgebra and the Weyl involution.
5. The Cartan decomposition. Maximal compact subgroups of real semisimple Lie groups, the conjugacy theorem.
6. The correspondence of real forms under a homomorphism of complex semisimple Lie algebras. A theorem of Karpelevich.
7. Representations of complex semisimple Lie algebras (short review). Inclusion between real forms, the index. Bilinear invariants of complex representations.
8. Representations of real semisimple Lie algebras. Conjugate representations. Classification of real and quaternionic representations.

Anatoli Vershik: Measure theoretic constructions and their applications in ergodic theory, asymptotics, combinatorics, and geometry, on Mondays, 15.30-17.30, ESI Lecture Hall, October 28, 2002 - December 2, 2002.

The notes of these courses will be published as ESI Lecture Notes.

Budget and visitors: The budget of ESI for 2002 was €780.700, of which €409.943 were spent on scientific activities and €351.346 on administration and infrastructure. Visitors supported from other (mainly non-Austrian) sources contributed the equivalent of a further €282.875.

The number of scientists visiting the Erwin Schrödinger Institute in 2001 was 433, and the number of preprints was 146.

Scientific Review

In November and December 2002 ESI was subject to a scientific review which was arranged as follows: after consultation with the Federal Ministry of Education, Science, and Culture, and following the same review procedure as the Austrian Academy of Sciences in recent years, the board of ESI (Vorstand des Vereines) asked J.-P. Bourguignon, director of IHES in Bures-sur-Yvette and member of the Scientific Advisory Committee of ESI, to select an independent review panel of 5 leading scientists and to appoint its chairman.

The composition of the review panel and its report can be found on page 141ff.

Programs in 2002

Developed Turbulence

Organizers: K. Gawedzki, A. Kupiainen and M. Vergassola.

Budget: €52.220.

Dates: May 15 – July 14, 2002.

Preprints contributed: [1176], [1179], [1180], [1181], [1190], [1192].

Report on the program

The program has brought to ESI 60 researchers, mathematicians working on hydrodynamical PDE's, theoretical physicists interested in analytical and numerical studies of statistical models of turbulent phenomena, and experimentalists involved in laboratory measurements of turbulent systems, for the global time of 730 days. The local expenses were covered by the ESI contribution, using about 85% of the allotted sum €61.700. 37 days, together with the travel expenses of five US based scientists, were covered by Clay Mathematics Institute. The program included a workshop 'Burgers Turbulence and Beyond' organized by U. Frisch and Ya. Sinai (May 27-31) with 22 presentations. a one-day event devoted to the Rayleigh-Bénard convection organized by D. Lohse (June 18), and a large number (29) of topical seminars. The general lectures Y. Brenier (on Monge-Ampère equations, a part of the Burgers workshop), by A.

Newell (on wave turbulence, June 19 and 21), by K. Moffatt (on magneto-hydrodynamical turbulence, June 25), by V. Zakharov (on condensation of sea waves, July 3) and a Wolfgang Pauli seminar by P. Markovich (on diffusive PDE's, June 27) were designed to stimulate contacts with the local community (which, unfortunately, remained somewhat sporadic).

The description of the context and of the aims of the ESI Program on Developed Turbulence, the complete list of visitors with the dates, as well as the seminar program, may be found on the web page that is transcribed below the present report. We shall then concentrate on a short description of the scientific content and the main scientific achievements of the two-months activity.

The topics discussed during the Burgers workshop included: the forced and unforced Burgers equation in one and several dimensions and its applications in cosmology, traffic jam modeling, and others; the use of the Monge-Ampere equation to solve the inverse Burgers equation with prescribed initial and final density fields (e.g. in reconstructing the early Universe from the present distribution of galaxies); dissipative anomalies for Burgers and incompressible Euler flows (including a review of so far unknown work of Lars Onsager); quasi-linear approximation to the Navier-Stokes equation; shell models for turbulence; dynamics of inverse cascades in 2D; Lagrangian aspects of passive scalar and nonlinear flows; blowup of Euler and Navier-Stokes solutions. Although the workshop did not achieved breakthroughs in open problems, some progress has been achieved towards the control of the forced Burgers equation in infinite space, in proving the absence of the enstrophy dissipative anomaly in 2D turbulence in the presence of friction, and in the blowup question for the quasi-linear approximation to the Navier-Stokes equation.

The questions of the behavior of Lagrangian trajectories in random ensembles of velocities and of its role in transport phenomena was an important topic of research. Progress was achieved in controlling such behaviors in two extreme cases: when the velocities are decorrelated in time and when they are time-independent. The first case (known under the name of Kraichnan model) has been studied intensively before. The progress here concerns the discovery of a new effect in the presence of intermediate compressibility and for intermediate Prandtl numbers: the 'sticky behavior' of trajectories. This behavior contradicts some earlier claims in literature. Its consequences for turbulent transport theory are presently investigated. For the time-independent case, the progress was achieved in analyzing the one-dimensional model with fractional-Brownian velocities (proof that trajectories stop in finite time, theoretical prediction of the behavior of exit times confirmed by the numerical analysis) and in understanding the role of sweeping effects in one and more dimensions.

For the first time an exact inequality has been obtained that indicates a Richardson-type power law behavior of the trajectory separation in the Navier-Stokes turbulence. The prefactor in the inequality requires, however, a refinement (presently, it blows up with the growing Reynolds numbers).

The behavior of Lagrangian trajectories is known to be responsible for dissipative anomaly and intermittency of passive scalar advection. One of the important results, partially achieved during the program, was the understanding of the difference between the behavior of the magnetic potential, which is an active scalar undergoing an inverse cascade, and the passive scalar exhibiting a direct cascade, in 2D conductive fluid. The difference was traced back to the specific correlations between scalar input and trajectories.

The ESI activity also served to advance the theoretical analysis of experiments studying pipe flows of visco-elastic polymer solutions that exhibit turbulent behavior already at low velocities and low Reynolds numbers. Studying the decay of passive scalar in such a flow has provided a simple test of the ideas on relation between Lagrangian dispersion and passive advection in the Batchelor regime of turbulence. Explanation of the originally unexpected long time behavior required that the theory be adapted to the finite geometry of the pipe. This removed the original discrepancy between the theory and the experiment. Further discussions allowed to plan new experiments and to asses the potential theoretical problems to which they give rise.

The aim of the convection day was to reevaluate the existing theories of thermal convection that are relevant for meteorology, geophysics, oceanography, and astrophysics. The recent experiments have drastically changed our view of the phenomenon. There was general agreement that there are no pure scaling laws for the Nusselt number and the Reynolds number as a function of the Rayleigh and the Prandtl number. The participant also agreed that the focus of future work should be on the aspect ratio dependence and on geometry effects. A progress was achieved in understanding the analogy between the Taylor-Couette and Rayleigh-Bérnard flow and the possibility of Bolgiano scaling for the structure

functions.

In wave turbulence, the main topic of research was the notion of entropy production and its role in the dynamical phenomena. There was also some progress achieved in understanding the behavior of higher correlation function in the Fermi acceleration (the Schrödinger equation in random time-decorrelated potential), the problem that relates to the non-linear Schrödinger equation as the Kraichnan model does to non-linear models of advection.

The most spectacular and entirely unforeseen result obtained during the program was the explanation of the previously conjectured relations between the stochastic Löwner evolution and 2D conformal field theory via an application of the idea of stochastically conserved quantities or zero modes, the objects first discovered in the study of the Kraichnan model of turbulent advection. The zero modes in the SLE/CFT correspondence appear to be a simple generalization of the ones relevant to the Batchelor regime of the Kraichnan model. Roughly, the generalization replaces the $SL(d, R)$ group by the (semi-)group of conformal transformation of the disc.

The articles containing the results mentioned above are often still in the process of elaboration and will be placed, after completion, at the ESI server (some already have been, as the preprint 1179 describing the SLE/CFT correspondence).

In conclusion, the program has been quite successful, creating an excellent opportunity for continuing old and starting new collaborations. It brought about a variety of expected, but also unexpected results. As compared to frequently run turbulence activities, it distinguished itself by creating an opportunity for interaction between a very wide spectrum of approaches to turbulence, from purely mathematical to experimental. It contributed this way to the strengthening of unity of science, a noble goal for an institution like ESI.

This program was supported by the Clay Mathematics Institute: Five U.S.-based scientists participated in the Program as emissaries of the Clay Mathematics Institute.

Workshop on Burgers turbulence and beyond. May 27-31 (organized by Uriel Frisch and Yasha Sinai as part of the Program 'Developed Turbulence').

Program:

KHANIN: Burgers turbulence in unbounded domains.
BEC: Hyperbolicity and statistics in forced Burgers turbulence.
GIRAUD: Burgers turbulence (homogeneous/ space-periodic / non-homogeneous) and its evolution in one dimension.
WEHR: Front speed in the Burgers equation with a random flux.

Burgulence: discussion.

BRENIER: The Monge-Ampere equation (lecture 1).
BRENIER: The Monge-Ampere equation (lecture 2).
FRISCH: Reconstruction of the primordial Universe: cosmological background, from the Burgers/adhesion model to the Monge-Ampere equation; presentation of the results.
SOBOLEVSKI: Reconstruction of the primordial Universe: implementation of the reconstruction hypothesis, cyclic monotonicity, mass transportation and the assignment problem.

Discussion on Monge-Ampere and Burgers:

AURELL: Burgers equation and the dynamics of stratified self-gravitating particles.
BLANK: Dynamics of traffic jams.
YAKHOT: Similarities of Burgers turbulence and real turbulence.

Discussion on Burgers turbulence and applications:

EYINK: An Historical Account of Onsager's Dissipation Anomaly.
DUCHON: Dissipation in weak Euler and Burgers solutions.
VANDEN-EINJDEN: Topic: dissipation and anomaly.
SINAI: Quasi-linear approximations of the 3d Navier-Stokes system.

Discussion on dissipation and Navier-Stokes.

JENSEN: Pulses in the Parisi continuum shell equations.
VASSILICOS: Lagrangian properties of Kinematic Simulations and their relation to Eulerian statistics.
BERNARD: Influence of friction on 2D enstrophy cascade.
GAWEDZKI: Variations on Lagrangian flow.

List of Participants: N. Antonov, J. Arponen, E. Aurell, M. Bauer, J. Bec, D. Bernard, L. Biferale, M. Blank, Y. Brenier, J. Bricmont, A. Celani, M. Cencini, M-L. Chabanol, M. Chertkov, S. Ciliberto, C.

Connaughton, P. Constantin (CMI emissary), T. Dombre, B. Dubrulle, J. Duchon, W. E (CMI emissary), G. Eyink, G. Falkovich, A. Fannjiang, U. Frisch, K. Gawedzki, C. Giraud, V. Hakulinen, P. Horvai, M. Jensen, K. Khanin, T. Komorowski, A. Kupiainen, S. Kurien, Y. Le Jan, E. Leveque, D. Lohse, J. Lukkarinen, N. Masmoudi, A. Mazzino, K. Moffatt, P. Muratore-Ginanneschi, S. Nazarenko, A. Newell (CMI emissary), P. Olla, G. Papanicolaou (CMI emissary), A. Pumir, O. Raimond, A. Shnirelman, Y. Sinai (CMI emissary), A. Sobolevski, V. Steinberg, E. Vanden Eijnden, C. Vassilicos, M. Vergassola, E. Villermaux, D. Vincenzi, A. Vulpiani, J. Wehr, V. Zakharov.

Arithmetic, automata, and asymptotics

Organizers: R. Tichy and P. Grabner.

Budget: ESI: €38.811, external sources: €2.025.

Dates: Spring 2002.

Preprints contributed: [1158], [1160], [1161], [1184], [1187], [1218].

The special semester on Arithmetic, Automata, and Asymptotics offered a wide-ranged scientific program. It brought together researchers from different areas such as number theory, ergodic theory, automata theory, asymptotic analysis, and average case analysis of algorithms. The intention of the program was to demonstrate the interplay between these areas and to initiate collaborations between researchers from these different fields. The program culminated in the two one week research conferences *Arithmetics and Automata*, April 8–12, 2002 and *Algorithms and Asymptotics*, July 1–5, 2002 both held in Graz. Furthermore, three seminar days (March 22, April 19, June 21) were held at the ESI in Vienna.

Workshop on arithmetics and automata. This workshop on Arithemtics and Automata was held in Graz, and was devoted to recent developments in the interplay between number theory, automata theory, and ergodic theory.

Program:

J.-P. Allouche (CNRS, France): Functions that are both p- and q-additive or multiplicative.
M. Bennett (Univ. of British Columbia): Products of consecutive integers.
D. Berend (Ben Gurion University, Israel): Some substitution sequences in number theory.
J.-M. Deshouillers (Univ. Bordeaux, France): Automatic aspects of the distribution modulo 1 of powers of algebraic elements in $\mathbb{F}_q((X))$.
K. Győry (Univ. Debrecen, Hungary): Distribution of solutions of decomposable form equations.
G. Hanrot (INRIA Lorraine, France): The Diophantine equation $\frac{x^n-1}{x-1} = y^q$.
E. Herrmann (Univ. Saarbrücken, Germany): Computing all S-integral solutions in a family of two simultaneous Pell equations.
I. Katai (Univ. Budapest, Hungary): Generalized number systems.
J. Kubilius (Univ. Vilnius, Lithuania): On some inequalities in the probabilistic number theory.
P. Liardet (Univ. Marseille, France): Dynamical properties of redundant numeration systems.
E. Manstavičius (Univ. Vilnius, Lithuania): Analytic and probabilistic problems of combinatorial structures.
A. Pethő (Univ. Debrecen, Hungary): On CNS polynomials.
A. van der Poorten (Macquarie Univ., Australia): Non-periodic continued fractions of formal power series and pseudo-elliptic integrals.
A. Schinzel (Univ. Warszawa, Poland): On power residues.
R. Tijdeman (Univ. Leiden, The Netherlands): Multi-dimensional versions of a theorem of Fine and Wilf and a formula of Sylvester.
G. Wüstholz (ETH, Zürich): Diophantine approximations in projective spaces.

Algorithms and Asymptotics. This research conference was held in Graz, and was devoted to topics from number theory, asymptotic combinatorics, and ergodic theory.

Program:

J.-P. Allouche (CNRS, France): About a sequence of Kimberling.
A. Baker (Cambridge):
F. Bassino (Univ. Marne la Vallée): About simple beta-numbers.
C. Baxa (Univ. Wien, Austria): Extremal values of continuants and transcendence of certain continued fractions.
V. Berthé (CNRS, France): Substitutions and arithmetical properties of Kronecker sequences.

H. Diamond (Univ. of Illinois, USA): An example of Beurling Primes with large Oscillation.
E. Fouvry (Univ. Paris, France): Some questions about Kloosterman sums.
H. Furstenberg (Hebrew Univ., Israel): Transversality of fractals, integral equations and a problem of D. Gale.
B. Hasselblatt (Tufts University, USA): Fractal dimension computed from stable and unstable slices.
H.-K. Hwang (Academia Sinica, Taiwan): A refined method of moments and its applications.
M. Levin (Bar-Ilan University, Israel): On completely uniformly distributed double sequences and pseudorandom double sequences.
P. Liardet (Univ. Marseille, France): Asymptotics of automatic random walks in random scenery.
C. Mauduit (CNRS, France): On the arithmetic structure of integers with a fixed sum of digits.
W. Philipp (Univ. of Illinois, USA): Pair correlations and U-statistics for sequences $\{n_k\omega\}$ and sequences of independent random variables.
H. Prodinger (Univ. Witwatersrand, South Africa): Exact and asymptotic enumeration problems arising from analysing algorithms.
J. Rivat (Univ. Nancy, France): Computational aspects of pseudorandom binary sequences.
A. Sarkőzy (Univ. Budapest, Hungary): Constructions of finite pseudorandom binary sequences.
J. Schmeling (Univ. Lund, Sweden): Zero entropy systems and Diophantine approximation.
N. Sidorov (UMIST, UK): Beta-expansions: uniqueness, complexity, dynamics.
B. Solomyak (Univ. Washington, USA): Fractals related to digit expansions in the complex plane.
M. Waldschmidt (Univ. P.et M. Curie, France): Syntaxic identities among harmonic series and automata.

Seminar days. Three seminar days on topics in number theory, ergodic theory, and uniform distribution were held at the Erwin Schrödinger Institute in Vienna.

March 22:
D. Masser (Univ. Basel): Some counting problems for algebraic points.
A. van der Poorten (Macquarie Univ., Australia): Regulators of quadratic number fields, continued fractions, and torsion on hyperelliptic curves.
H.P. Schlickewei (Univ. Marburg): Gap principles in diophantine approximations.

April 19:
Y. Bilu (Univ. Bordeaux, France): Sprindzhuk's theorem is easy.
K. Győry (Univ. Debrecen, Hungary): Almost perfect powers in products of consecutive terms of arithmetic progressions.
A. Schinzel (Polish Academy of Sciences): A theorem on polynomials with an application to Siegel's Lemma.
W. Schmidt (Univ. of Colorado): Some exponential diophantine equations.

June 21:
W. Chen (Macquarie Univ., Australia): Upper bounds in discrepancy theory.
W. Philipp (Univ. of Illinois, USA): Metric theorems for discrepancies and distribution measures of sequences $\{n_k\omega\}$.
N. Sidorov (UMIST, UK): The realm of beta-expansions.
W.D. Brownawell (Pennsylvania State Univ., USA): A sharp Liouville-Lojasiewicz inequality.
M. Smorodinsky (Tel Aviv University, Israel): Asymptotic independence properties. Two ways of coding a stationary process from an i.i.d. process.

Conclusion. The special semester on Arithmetic, Automata, and Asymptotics was a very successful scientific program that offered the opportunity of interaction between researchers from different areas of mathematics. Several cooperations were initiated during this program and are still ongoing.

Invited Scientists: Jean-Paul Allouche, Alan Baker , Christoph Baxa, Valerie Berthe, Yuri Bilu, W. Dale Brownawell, Alexander Bufetov, William Chen, Jean-Marc Deshouillers, Harold G. Diamond, Etienne Fouvry, Christiane Frougny, Kálmán Göry, Guillaume Hanrot, Boris Hasselblatt, Jonas Kubilius, Mordechai Levin, Pierre Liardet, Eugenijus Manstavicius, Christian Mauduit, Matthew Papanikolas, Helmut Prodinger, Joel Rivat, András Sa'rközy, Andrzej Schinzel, Jörg Schmeling, Hans Peter Schlickewei, Nikita Sidorov, Boris Solomyak, Alfred van der Poorten, Michel Waldschmidt, Gisbert Wüstholz.

Quantum field theory on curved space time

Organizers: K. Fredenhagen, R. Wald and J. Yngvason.

Budget: €41.573.

Dates: July-August, 2002.

Preprints contributed: [1121], [1149], [1156], [1157], [1163], [1164], [1183], [1185], [1186].

Report on the program

The main goal of this program was to bring together researchers with expertise in general relativity and researchers with expertise in mathematical aspects of quantum field theory, in order to address some problems of mutual interest in quantum field theory in curved spacetime. Approximately 25 researchers in quantum field theory in curved spacetime and related areas participated in this two-month program. The program was extremely successful in promoting considerable productive interaction between groups of researchers who generally have had only limited interaction with each other. The 'cross-fertilization' and new collaborations initiated by these interactions are likely to bear fruit for many years to come.

The program covered many topics in quantum field theory and related areas. The most significant focus was on five topics.

Perturbative renormalization of quantum fields in curved spacetime. A great deal of progress has been made in recent years in characterizing the 'ultraviolet divergences' of quantum fields in curved spacetime and developing renormalization theory for interacting quantum fields. Seminars by S. Hollands, K. Fredenhagen, R. Verch, and R. Wald reported on this recent progress. The difficulties resulting from the lack of a preferred vacuum state and a preferred Hilbert space representation of the canonical commutation relations for the free field have been overcome by formulating the theory within the algebraic approach. The difficulties associated with the lack of a global notion of a Fourier transform (so that the usual momentum space methods for renormalization cannot be used) have been overcome by the use of the methods of 'microlocal analysis'. Finally, the difficulties associated with the absence of a notion of 'Poincare invariance' (or any other symmetries) in general curved spacetime have been overcome by imposing the condition that the quantum fields of interest be constructed locally and covariantly out of the spacetime metric. The upshot is that perturbative renormalization theory for quantum fields in curved spacetime is now on as sound a footing as in Minkowski spacetime. Furthermore, theories that are renormalizable in Minkowski spacetime will also be renormalizable in curved spacetime, although additional 'counterterms' corresponding to couplings of the quantum field to curvature will arise.

The role of 'ultraviolet behavior' (above the Planck scale) in the Hawking effect. Although the Hawking effect was derived more than 25 years ago, there remains a difficulty with the derivation in that it relies on the properties of quantum fields in a regime where one has no right to expect quantum field theory in curved spacetime to be a good approximation. Specifically, consider the modes of the quantum field that correspond to 'particles' that are seen by observers near infinity to emerge from the black hole at late times. When traced backward in time, these modes become highly blueshifted and correspond to 'transplanckian' frequencies and wavelengths at early times. Thus, the Hawking effect appears to rely on assumptions concerning the initial state and behavior of degrees of freedom in the transplanckian regime. Similar issues also arise in cosmology when considering the 'quantum fluctuations' responsible for the formation of large scale structure at late times. Seminars by Jacobson and Unruh explained the nature of the transplanckian issues and described some simple models where the effects of modifying dynamical laws in the transplanckian regime can be analyzed. These models support the view that the Hawking effect is robust with respect to changes in physical laws in the transplanckian regime.

Positive energy properties of quantum fields in curved spacetime. It is well known that in quantum field theory in flat or curved spacetime, the expected energy density at a point can be made arbitrarily negative. However, during the past ten years, some global restrictions on negative energy have been derived. In particular, 'quantum inequalities' have been derived, which put a lower bound on the energy density measured along the worldline of an observer with a (smooth, compact support) 'sampling function' $f(\tau)$. Originally, such bounds were derived by non-rigorous methods in certain special cases, but recently a rigorous and completely general derivation of quantum inequalities has been given using the methods of microlocal analysis. Many issues remain open, however, such as the derivation of optimal bounds and the precise status of the average null energy condition (which asserts the non-negativity of the integral over a complete null geodesic of the stress energy tensor contracted twice with the tangent to the null geodesic). These issues were explored in seminars by Ford, Fewster, Roman, Flanagan, and

Pfenning. In research arising directly from discussions occurring during the program, progress also was made toward deriving quantum inequalities for quantities other than the stress-energy tensor.

The interplay between global aspects of spacetime and the properties of quantum fields. In the algebraic formulation of quantum field theory, global aspects of spacetime are reflected by certain properties of the state space. On Minkowski space this leads to the theory of superselection sectors (structure at spacelike infinity) and to scattering theory (timelike infinity) with a special role played by null infinity (infrared problem).

Especially interesting are the so called wedge regions, which are subregions of Minkowski space which are bounded by two null planes, one in the future, the other in the past. It was a basic discovery of Bisognano and Wichmann that the vacuum state on the algebra of observables associated to a wedge region is a KMS state with respect to a 1-parameter subgroup of the Poincare group. The orbits of this group stay within the wedge and are the orbits of uniformly accelerated observers. One thus obtains an operator algebraic explanation of the Unruh effect. The underlying mathematical theory is the modular theory of Tomita and Takesaki.

Concerning quantum field theory on curved spacetimes, a major problem is to determine the analogs of wedge regions and to exhibit states where the corresponding modular transformations have a geometrical meaning. This program was successful in de Sitter space as discussed by Guido, as well as, to a certain extent in Robertson-Walker spacetimes. In Anti-de Sitter spacetime the wedges are in one to one correspondence to double cones in the Minkowski space at spacelike infinity. One thus obtains an algebraic version of AdS-CFT correspondence which was discovered by Rehren. To understand this correspondence in more detail an interesting relation between limits of fields at the boundary and the partition function for specified boundary values was described in the talk by Rehren.

Another major problem is the actual computation of the modular transformations. In the talk by Yngvason it was described how the modular transformations for generalized free fields can be determined, and it was discussed, whether the principle of modular geometric action as formulated by Buchholz and Summers may be valid in more general space times.

One difficult problem in quantum field theory on curved spacetimes is the choice of reference states, comparable to the vacuum or to one-particle states in Minkowski states. In the talk of Buchholz, a concept of local equilibrium states was presented. These are states which coincide at each single point on a finite number of fields with a homogenous KMS states on Minkowski space. Applied to states on Minkowski space it turned out, that a local equilibrium state always satisfies the kinetic equations, moreover, if the state is not in global equilibrium, the condition of local equilibrium can at most hold within a future lightcone, so that every maximal local equilibrium state stems from a singularity at the vertex of the light cone ('hot bang'). The analogy of this result with standard cosmology and an interpretation of the future lightcone as an expanding Robertson-Walker spacetime were intensively discussed as well as the possible applications of this concept to the interpretation of states on curved spacetimes.

Loop variables/quantum geometry approach to quantum gravity. In the loop variables/quantum geometry approach to quantum gravity taken by Ashtekar and collaborators, one first defines a 'kinematical Hilbert space' and then tries to define the action of the Hamiltonian constraint operator on these 'kinematical states'. In this approach, the Hamiltonian constraint operator is not intrinsically well defined (i.e., 'regularization' is needed), but the nature of this regularization appears to be very different from the usual regularization of 'ultraviolet divergences' occurring in quantum field theory. One of the goals of our program was to explore the nature of renormalization in the loop variables/quantum geometry approach to quantum gravity and to understand its relationship to renormalization in ordinary quantum field theory. Seminars by Lewandowski, Perez, Ashtekar, Thiemann, Bojowald, Fairhurst, and Sahlmann described in detail various aspects of the loop variables/quantum geometry approach. The extended interactions between the researchers in the loop variables/quantum geometry approach and researchers in quantum field theory resulting from these seminars as well as from numerous private discussions were very fruitful. In particular, considerable progress was made in finding simple quantum field theory analogs of the constructions used in the loop variables/quantum geometry approach.

List of lectures:

Ted Jacobson (Maryland): The Transplanckian Question for Hawking Radiation and Cosmology.
Larry Ford (Isaac Newton Institute): Constraints on Negative Energy Densities in Quantum Field Theory.
Wolfgang Junker (Albert-Einstein-Institut): An Introduction to Microlocal Analysis and Quantum Field Theory in Curved Spacetime.
Bill Unruh (British Columbia): Black Hole Analogs.
C.J Fewster (York): Three Perspectives on Quantum Inequalities.
Tom Roman (Connecticut): Constraints on Spatial Distributions of Negative Energy.
Stefan Hollands (Chicago): An Introduction to Quantum Field Theory in Curved Spacetimes I: The Basic Problems.
Klaus Frendenhagen (Hamburg): An Introduction to Quantum Field Theory in Curved Spacetimes II: The Epstein-Glaser Approach.
Rainer Verch (Goettingen): An Introduction to Interacting Quantum Field Theory in Curved Spacetime III: The Role of General Covariance.
Stefan Hollands (Chicago): An Introduction to Interacting Quantum Field Theory in Curved Spacetime IV: Handling the Finite Renormalization Ambiguities.
R. Verch (Goettingen): Mathematical Aspects of Some Recent Developements in Quantum Field Theory on Curved Spacetimes.
Jerzy Lewandowski (Warsaw): Introduction to Quantum Geometry.
Eanna Flanagan (Cornell): Quantum Inequalities on 2-Dimensional Spacetimes.
Alejandro Perez (Pennsylvania): Spin Foam Quantization of Gravity: A Finite Model.
Bill Unruh (British Columbia): Circular Acceleration, Acceleration Radiation, and Electron Thermometers.
Robert Wald (Chicago): The present Status of Quantum Field Theory in Curved Spacetime.
Chris Fewster (York): Quantum Inequalities: Restriction on Negative Energy Densities in QFT.
Detlev Buchholz (Heidelberg): Local Equilibrium, Hot Bangs, and the Arrow of Time in Relativistic Quantum Field Theory.
Abhay Ashtekar (Pennsylvania): Quantum Geometry and its Applications: An Overview.
Klaus Fredenhagen (Hamburg): Canonical Formalism Without a Space/Time Splitting.
Thomas Thiemann (Albert-Einstein-Institut): Towards the Quantum Einstein Equations.
Jakob Yngvason (ESI): The Modular Structure of Generalized Free Fields.
Martin Bojowald (Pennsylvania): Loop Quantum Cosmology.
Karl-Henning Rehren (Goettingen): A Comment on the 'Dual Field' in the AdS-CFT Correspondence.
Daniele Guido (L'Aquila): Modular Localiztion, Dethermalization and the dS-CFT Correspondence.
Robert Wald (Chicago): Remarks on Inflation.
Steve Fairhurst (Alberta): Shadow States in Quantum Gravity.
Hanno Sahlmann (Golm): QFT on Quantum Geometry.
Mitch Pfenning (York): Quantum Inequalities for Spin One Fields.

Aspects of foliation theory in geometry, topology and physics

Organizers: Franz W. Kamber (Principal Organizer), James F. Glazebrook, Kenneth Richardson, Peter W. Michor (Local Coordinator).

Budget: ESI: €76.875, external sources €52.500.

Dates: mid-July – December, 2002.

Preprints contributed: [1188], [1189], [1207], [1211], [1212], [1219], [1222], [1223], [1225], [1244], [1245], [1249], [1252], [1266], [1267], [1268], [1270], [1278].

Report on the program

1. Organization of the Program. A semester–long program on various aspects of Foliation Theory was organized at the Erwin Schroedinger International Institute for Mathematical Physics from July 15 to November 30, 2002 (with a break in August due to the ICM in Beijing). The program consisted of a series of activities listed with approximative dates. It should be understood that there were correlations between the various topics and therefore there were some overlaps during the program.

1. Geometry and Topology of Foliations / Mid-July to mid-August;
2. Noncommutative Geometry of Foliations / September–October;
3. Index and spectral theory in Foliations / September–October;

4. Riemannian Foliations / October;

5. Joint ESI/EDGE workshop on 'Geometry and Physics' / November 11–22;

6. Foliations in low dimensions / November.

About 90 mathematicians visited the ESI during the program. The average duration of the visit was about 2 weeks, with a few key participants staying for four weeks. The majority of participants came from the EU, Japan and the USA, with most EU countries as well as Switzerland being represented. Other participants came from Hungary, Israel, Korea, Poland, Romania, Russia, Serbia/Montenegro, Singapore, Slovenia and Tunesia. Within the constraints of the budget, we invited young researchers, mainly on the suggestion of senior participants.

While most prinicipal members of the foliation community accepted our invitation to visit the ESI, we regretted that some prominent members, notably E. Ghys and S. Hurder, were not able to accept our invitation. Otherwise, the list of participants is fairly comprehensive.

2. Financial aspects of the Program. The ESI budget (after reduction) for the program was €79,000. We were fortunate to be able to augment the program budget from several sources. Peter Michor, Scientific Director of ESI, made a generous contribution in the form of visitor appointments from from his project with the 'Fonds zur Förderung der wissenschaftlichen Forschung'. Thanks to the initiative of Oscar García–Prada, the EU networks EDGE and EAGER supported a number of their members during the joint ESI–EDGE workshop on 'Geometry and Physics' in November and helped to make the workshop possible. The Clay Mathematics Institute supported our activities under their Mathematical Emissary Program and enabled us to cover travel expenses for a few US participants. This additional financial support is hereby gratefully acknowledged.

While it is not possible to put an exact value on this additional support, it is a fair estimate that the total budget for our program activities, extending over five months and involving about 90 participants, was €100.000.

3. Scientific Activities. The scientific aims of the program were to bring together an international group of experts to establish the state of the art in the subject and to encourage interaction and cooperation among the participants.

For this reason, we decided from the beginning to create a relaxed working climate, thereby encouraging discussion and collaboration among participants. This meant among other things that as a rule we limited lectures to two weekdays (Tuesdays and Thursdays), with about three lectures on those days. The participants seemed to appreciate this and we got many positive comments about the positive working climate at the ESI. Many participants came with a specific collaboration in mind and new projects were started as well.

4. Highlights of the program. In late July / early August (weeks 3 and 4) the presence of a substantial number of 'classical' topologists and geometers spontaneously resulted in a workshop on 'Geometry and Topology of Foliations'. During September, the presence R. Bott, A. Connes, A. Haefliger, N. Higson, H. Moscovici and others attracted substantial attention, with the emphasis being on non–commutative Geometry and Index Theory for Foliations. Finally, the ESI–EDGE workshop in November was given focus by the presence of Ph. Candelas and N. Hitchin.

A documentation of the program, including a list of participants, dates of attendance, lectures and abstracts is appended to this report and we refer to it for details of the scientific activities. The complete documentation, including in addition links to participants homepages as well as a photogallery, can be accessed via the ESI website http://www.esi.ac.at under 'Past Activities'. Ken Richardson served as webmaster for our program.

5. Coordination with other scientific programs. During Fall 2002 (September-November) the ESI also hosted a concurrent program on 'Noncommutative Geometry, Feynman Diagrams and Quantum Field Theory', organized by H. Grosse, D. Kreimer, J. Madore, J. Mickelsson and I. Todorov. The

organizers of both programs coordinated some of their activities. This was especially the case during September when A. Connes was visiting the ESI, and during the ESI–EDGE workshop in November with the participation of Ph. Candelas and N. Hitchin. The idea was to foster and encourage exchange and interfaces between Mathematics and Mathematical Physics.

6. Cultural and social activities. On the premise that mathematics and music have a great affinity, we decided to organize social activities around a number of musical events. Good relations were established with the Wiener Priesterseminar (WPS), whose Administration (especially Frau Penkler) graciously made it possible for us to use some of their facilities. In early August, and then again in November, Izumi Mitsumatsu gave a Piano Recital in the Music Room (Kulturraum) of the WPS. In early September, the young Bulgarian violinist Bojidara Kouzmanova gave a wonderful Violin Recital in the Seminary Church with works of J. S. Bach and S. Prokofiev. In late October we organized a Jazz Party in the Common Room of the ESI with the Paul Fields Quartet (Violin, 2 Guitars and Bass) and Ken Richardson on the Alto Saxophone. All these concerts were well attended and were enthusiasically received by the audience consisting mainly of ESI visitors and their families and friends.

In September, we began to serve coffee, tea and cookies in the afternoon between lectures and eventually every afternoon during the week. This was much appreciated by the participants. In all this the cooperation and assistance of the ESI staff was essential and is gratefully acknowledged.

We requested and were granted an increase in the entertainment fund to 3 percent of our ESI budget. The above activities amounted to a total expense of €3250. Participant contributions were about €1000 for a net expenditure of €2250 from ESI funds, which was within budget.

Invited Scientists: Luis Alvarez-Consul, Marek Badura, Moulay-Tahar Benamour, Dorota Blachowska, Emmanuel Blanc, Michel Boileau, Raoul Bott, Steven Bradlow, Mark Brittenham, Ronald Brown, Jochen Brúning, Alberto Candel, Philip Candelas, Mohamed Ali Chouch, Lawrence Conlon, Marius Crainic, Joachim Cuntz, Maciej Czarnecki, Johan L. Dupont, Alaohi El Kacimi, Sergio Fenley, Oscar Garcia-Prada, Victor Ginzburg, James F. Glazebrook, Sebastian Goette, Andre Haefliger, Gilbert Hector, James Heitsch, Nigel Higson, Nigel Hitchin, Ko Honda, Johannes Huebschmann, Adrian M. Ionescu, Alessandra Iozzi, Seoung Dal Jung, Franz W. Kamber, Jerry Kaminker, William H. Kazez, Jerzy Konderak, Iouri Kordioukov, Dieter Kotschick, Jeffrey Lee, Daniel Lehmann, Alvarez Jesus Antonio López, Gordana Matic, Habib Marzougui, Shigenori Matsumoto, Yoshihiko Mitsumatsu, Shigeaki Miyoshi, Izak Moerdijk, Hitoshi Moriyoshi, Henri Moscovici, Janez Mrcun, Ignasi Mundet, Vicente Munoz, Ryszard Nest, Peter Newstead, Victor Nistor, Peter Pang, Tony Pantev, Efton Park, Paolo Piazza, Raphael Ponge, Ken Richardson, Paul A. Schweitzer, Sorin Dragomir, Andras Szenes, Svjetlana Terzic', Takashi Tsuboi, Izu Vaisman, Thomas Vogel, Elmar Vogt, Pawel Walczak, Daniel Waldram, Robert Wolak.

Noncommutative geometry and quantum field theory, Feynman diagrams in mathematics and physics

Organizers: H. Grosse, J. Madore and J. Mickelsson, D. Kreimer and I. Todorov.

Budget: ESI: €63.450, external sources: €5.625.

Dates: Fall 2002.

Preprints contributed: [1138], [1193], [1201], [1217], [1220], [1221], [1227], [1228], [1229], [1231], [1232], [1236], [1237], [1239], [1251], [1258], [1271].

Report on the program

Feynman diagrams provide a universal means to organize the perturbative expansion of a quantum field theory. While in some lucky cases we are able to progress beyond the perturbative approach, it turns out that Feynman diagrams themselves are a source of fascinating mathematical problems. They are naturally connected to configuration spaces, with their singularities located along diagonals of coinciding vertices. The stratification of these singularities by rooted trees, emphasized for example by Fulton and

MacPherson, makes it rather natural that the process of renormalization is combinatorially based on a Hopf algebra of rooted trees that is a universal object which contains the Hopf algebra of iterated integrals as well as the Connes-Moscovici Hopf algebra of diffeomorphisms as sub-algebras.

The above was the scientific motivation for a workshop which brought together practitioners of quantum field theory and mathematicians working on number theory and operads. The three weeks of overlap led to lively exchange beneficial to both sides.

For example, Goncharovs algebraic approach to generalized polylogarithms resonated with the computational experiemce of a QCD practitioner like Stefan Weinzierl and A. Isaev, while Kreimer used the opportunity to explore the Hopf algebra of graphs in detail with him, as well as with Stasheff, Markl and Shnider (the operadchiks).

While the first three weeks were dedicated to the Connes-Kreimer Hopf-algebras and the applications to quantum field theory and number theory, we concentrated within the next 10 weeks mainly on subjects like quantum groups and general deformations, deformation quantization and gerbes, noncommutative quantum field theory, noncommutative geometry and classical field theory and the connection to string theory.

The quantum group part was governed by lectures of Dubrovin, Schmüdgen, Zhang, Arai, Dobrev, Fiore and Schlichenmaier. Representation theory of quantum groups, the deformed Riemann-Hilbert problem, cohomology theory, invariant equations, invariant models, braided tensor product structures and the general deformation methods were reviewed. Steinacker, Aschieri and Bonetti applied the quantum group symmetry to gauge models on deformed spaces, especially spheres.

Connes' lecture concerned the spectral triple for the q-deformed $SU_q(2)$ algebra. Within a special base a Dirac operator is defined, a trace on the algebra of pseudodifferential operators exists, the analog of Poincare classes and cyclic cocycles have been defined, in short, a quantum group covariant calculus was presented and the first example of a spectral triple on q-deformed algebras is found.

Gerbes were mentioned in a number of contributions: motivated by the introduction of the B-field in string theory they occur also in field theries with Wess-Zumino terms, they allow to formulate anomalies on odd dimensions, are the framework for the monopole equations and are connected to a nontrivial Dixmier-Douady class and twisted K-theory. Some of these aspects entered the talks of Jurco, Felder, Severa, Uribe, Lupercio, Carey and Mickelsson.

The next big subject concered quantum field theory on deformed spaces: Formulation of models over Minkowski or Euclidean spaces is easy, to establish renormalization questions and to establish a sensible calculus is still obscure and unsolved: Wulkenhaar reviewed the subject especially emphasizing the IR/UV mixing. Bahns presented the Yang-Feldman formulation and Liao presented the common work with Sibold on the time ordered formulation of models defined on deformed Minkowski space-time. Langmann presented special three dimensional models with magnetic fields and Rajeev showed the connection to matrix models and entropy problems.

Many aspects of classical field theory are described by spectral triples. The gereral review concerning the unification of gravity and the standard model was given by Schücker and treated by Presnajder. Madore showed that noncommutativity allows to smoothen the big bang singularity, spectral triples over pseudo-Riemannian spaces were formulated by Strohmaier.

In a number of contributions the connection to strings was mentioned. A nice review of Mirror symmetry was given by Klemm. The connection of strings, matrix models, gauge thories and the Dijkgraf-Vafa conjecture was given by Theisen.

There was a lively interaction not only among the visitors of our project but also with the visitors of the mathematical project on foliations organized by Kamber and Richardson. There were not only common concerts and cookies, but the discussions on subjects of common interest made it a very lively event.

Invited Scientists: Asao Arai, Paolo Aschieri, Dorothea Bahns, Francesco Bonechi, Bernhelm Booss-Bavnbek, Martin Bordemann, David Broadhurst, Alan L. Carey, Pierre Cartier, Alain Connes, Ludwik Dabrowski, Goran Djordjević, Vladimir Dobrev, Michel Dubois-Violette, Boris Dubrovin, Askar Dzhumadil'daev, Giovanni Felder, Gaetano Fiore, R. Flume, Herbert Gangl, Alexander Goncharov, Ralf Holtkamp, Alexei Isaev, Branislav Jurčo, Takashi Kimura, Ivo Klemes, Albrecht Klemm, Ivan Kostov,

Dirk Kreimer, Giovanni Landi, Edwin Langmann, Eric Leichtnam, Matthias Lesch, Yi Liao, Jean-Louis Loday, Juha Loikkanen, Ernesto Lupercio, Marco Maceda, John Madore, Martin Markl, Jouko Mickelsson, Anna Maria Paoluccia, Sylvie Paycha, Ludwig Pittner, Slobodan Prvanović, Peter Prešnajder, Sarada G. Rajeev, Andreas Recknagel, Christian Rupp, Samuel Rydh, Karl-Georg Schlesinger, Martin Schlichenmaier, Konrad Schmüdgen, Thomas Schücker, Albert Schwarz, Pavol Ševera, Steven Shnider, Petr Somberg, James Stasheff, Harold Steinacker, Thomas Strohmaier, Stefan Theisen, Bernardo Uribe, Stefan Weinzierl, Paul B. Wiegmann, Michael Wohlgenannt, Raimar Wulkenhaar, Konstantin Zarembo, Ruibin Zhang.

Mathematical population genetics and statistical physics

Organizers: E. Baake, M. Baake and R. Bürger.

Budget in 2002: ESI: €26.775, external sources: €9.075. A further €31.500 will be made available for this program in 2003.

Dates: November 2002 – February 2003.

This program is still going on, so the report will be completed next year.

Invited Scientists in 2002: Ellen Baake, Nicholas Barton, Matthias Birkner, Anton Bovier, Reinhard Bürger, Donald Dawson, Kevin J. Dawson, József Garay, Tini Garske, Sergey Gavrilets, Alexander Gimelfarb, Andreas Greven, Uwe Grimm, Ralph Haygood, Joachim Hermisson, Toby Johnson, Valery Kirzhner, Markus Klein, Achim Klenke, Sabin Lessard, Yuri Lyubich, Carlo Matessi, Vladimir Passekov, Luca Peliti, Oliver Redner, Christoph Richard, Francesca Tria, Michael Turelli, Günter Wagner, Anton Wakolbinger, Benjamin Yakir, Iljana Zähle.

Workshops organized outside the main programs

Winter school in geometry and physics

January 12–19, 2002, Srní, Czech Republic, with a contribution by ESI of €1.000. The proceedings will be published in Suppl. Rend. Circ. Mat. Palermo, II. Ser.

Arithmetic Groups and Automorphic Forms

January 27 – February 2, 2002, organized by Joachim Schwermer (University of Vienna). This workshop was financed with €11.100 through the share of K. Schmidt, foreign support was €900.

Program:

J. Labesse: The principles of trace formula stabilization.
J. Schwermer: On the Eisenstein cohomology of arithmetic groups.
M. Harris: Congruences between endoscopic and stable forms on unitary groups.
S. Kudla: Integrals of Borcherds forms.
H. Carayol: Cohomological realization of some Maass-type automorphic representations.
J. Burgos: Arithmetic Chow rings of non compact Shimura varieties.
J. Cogdell: On lifting from classical groups to GL_n.
U. Weselmann: The twisted topological trace formula and liftings from GSp_4 to GL_4 and GL_5.
G. Harder: Eisenstein cohomology and mixed motives.
J. Tilouine: Modularity of certain rank form symplectic Galois representations.
I. Mahnkopf: Cohomology of arithmetic groups, parabolic subgroups and special values of L-functions for GL_n.
L. Ji: Scattering flats and matrices of locally symmetric spaces.
S. Rallis: Automorphic Descent and the Relative Trace Formula for Classical Groups.
V. Heiermann: Special representations and spectral decomposition for a p-adic group.

Participants: Sigfried Böcherer, Jan Bruinier, José, Ignacio Burgos Gil, Henri Carayol, Alexander Caspar, Laurent Clozel, James W. Cogdell, Jens Franke, Fritz Grunewald, Paul Gunnells, Günter Harder, Michael Harris, Volker Heiermann, Lizhen Ji, Stephen S. Kudla, Ulf Kühn, Jean-Pierre Labesse, David Mauger, Martin Olbrich, Stephen Rallis, Jürgen Rohlfs, Ulrich Stuhler, Jacques Tilouine, Eric Urban, Uwe Weselmann.

Stability matters: A symposium on mathematical physics in honor of Elliott H. Lieb

July 28 - August 2, 2002. This symposium was organized by T. Hoffmann-Ostenhof, H. Grosse, H. Narnhofer, K. Schmidt, W. Thirring and J. Yngvason on the occasion of Elliott Lieb's 70th birthday.

Program:

J. Yngvason: Elliott Lieb's Contributions to Mathematical Physics.
J.P. Solovej: The Matter of Instability.
R. Seiringer: Proof of Bose-Einstein Condensation for Dilute Trapped Gases.
J. Fröhlich: The KMS condition.
K. Hepp: On the Continuum Limit in the Lovely Happy Laser.
M. Loss: A Bound on Binding Energies and Mass Renormalization in some Models of Quantum Electrodynamics.
H. Siedentop: The Hartree-Fock Equations of the Relativistic Electron-Positron Field.
P. Choquard: New Results in the Theory of One-Dimensional Conservative Liquids.
D. Szasz: Hard Ball Systems and the Lorentz Process.
M. Aizenman: On the Spectral and Dynamical Properties of Schrödinger Operators with Random Potentials.
Y. Sinai: $(3x + 1)$ and other number-theoretic dynamical systems.
J. Chayes: Phase Transitions in Combinatorial Optimization.
B. Jancovici: Two-Dimensional Coulomb Systems: A Minireview of Exact Results.
R. McCann: Fast-Diffusion to Self-Similarity: Complete Spectrum, Long-Time Asymptotics, and Numerology.
H.-T. Yau: Classification of Asymptotic Dynamics for Nonlinear Schrödinger Equations with Small Initial Data.
Session on human rights and the responsibility of scientists, organized by J. Lebowitz.
A. Jaffe: Twisting Supersymmetry.
E. Carlen: A Spherical analog of the Sharp Young's inequality and Related Topics.
R. Benguria: Speed of Propagation of Travelling Fronts for Reaction-Diffusion Equations.
L. Erdös: Derivation of the Nonlinear Schrödinger equation from a Many Body Coulomb System.
J. Lebowitz: Stationary Nonequilibrium States and the Continuing Quest for a Proof of Fourier's Law.

Participants: D.B. Abraham, Peter C. Aichleburg, Michael Aizenmann, Joseph Avron, Michael Baake, Claude Bardos, Rafael Benguria, Bernhard Bodmann, Christian Borgs, Almut Burchard, Eric Carlen, Maria da Conceicao Carvalho, Isabelle Catto, Jennifer Chayes, Philippe Choquard, Gianfausto Dell'Antonio, Michael Duetsch, Karen Elsner, Franz Embacher, Gerard Emch, László Erdős, Pavel Exner, Jürg M. Fröhlich, Gian Michele Graf, Marcel Griesemer, Harald Grosse, Christian Hainzl, Klaus Hepp, Helmuth Hüffel, Arthur Jaffe, Bernard Jancovici, Norbert Kaiblinger, Vladimir Korepin, Roman Kotecký, Oscar E. Lanford, Ari Laptev, Joel Lebowitz, Michael Loss, Kishore B. Marathe, Robert McCann, Johanna Michor , Bruno Nachtergaele, Dorte Olesen, Leonid Pastur, Gert K. Petersen, Robert Schrader, Erhard Seiler, Ruedi Seiler, Israel Michael Sigal, Wolfgang Spitzer, Herbert Spohn, Daniel Sternheimer, Domokos Szász, Daniel Ueltschi, Simone Warzel, Kenji Yajima, Horng-Tzer Yau, Minoru W. Yoshida, Jean-Claude Zambrini, Eberhard Zeidler, Heribert Zenk.

Visitors outside the main programs

Visitors to ESI not associated with any of the main programs and workshops have so far contributed the preprints [1124], [1130], [1165], [1131], [1132], [1155], [1050], [1182], [1191], [1125], [1127], [1128], [1134], [1138], [1139], [1142], [1154], [1155], [1159], [1165], [1166], [1175], [1177], [1178], [1182], [1191], [1200], [1203], [1206], [1210], [1214], [1216], [1225], [1234], [1235], [1238], [1240], [1241], [1242], [1243], [1253], [1254], [1256], [1259], [1262], [1263], [1264], [1272], [1273]. This lists includes preprints contributed by the Senior Research Fellows and their collaborators.

ESI spent €51.789, with external contributions amounting to €174.575. These figures do not include the invitations issued by the Senior Research Fellows which are budgeted separately.

Guests of A. Cap. Rod Gover, Jan Slovak, Vladimir Souček.

Guests of P. Michor. Dmitri Alekseevsky, Marc Burger, Krzysztof Galicki, Boris Khesin, Jacques Laskar, Mark V. Losik, Dénes Petz, Markus Pflaum, Andrei Prasolov, Armin Rainer, Shoji Yokura.

Guests of K. Schmidt. Siddhartha Bhattacharya, Geon Ho Choe, Moshe, Eli Glasner, Vadim Kaimanovich, Robert Langlands, David Masser, Byoung Ki Seo.

Guests of J. Yngvason. Dmitri Vasilevich, Hans-Jürgen Borchers, Elliott Lieb, Luiz Alberto Manzoni, Bert Schroer.

Guests of Shrikrishna G. Dani. Yves Guivarch, Michael McCrudden.

Guests of Arkadi Onishchik. Mikhail Bashkin, Vladimir Gorbatsevich.

Guests of Ivan Todorov. Bojko Bakalov, Ludmil Hadjiivanov, Nikolay Mitov Nikolov.

Guests of Anatoli Vershik. Anna Erschler, Alexandre Gorboulski.

Programs and workshops approved for the years 2003 – 2004

The year 2003

Workshop on idempotent mathematics

Organizers: V. Maslov, G. Litvinov.

Budget: €15.750.

Dates: Early spring 2003.

Kakeya-related problems in analysis

Organizers: A. Iosevich, Izabella Laba, D. Müller.

Budget: €56.250.

Dates: February 15 – April 15, 2003.

Penrose inequalities

Organizers: R. Beig, W. Simon, P. Chruściel.

Budget: €67.500.

Dates: June-July, 2003.

Gravity in two dimensions

Organizers: W. Kummer, H. Nicolai, D.V. Vassilevich.

Budget: €56.250.

Dates: Fall 2003.

Moment maps and Poisson geometry

Organizers: Anton Alekseev, Tudor Ratiu.

Budget: €78.750.

Dates: July 1 – November 30, 2003.

The year 2004

Geometric and analytic problems related to Cartan connections

Organizers: T. Branson, A. Cap, J. Slovak.

Budget: €67.500.

Dates: Spring 2004.

Tensor categories in mathematics and physics

Organizers: J. Fuchs, Y.-Z. Huang, A. Kirillov, M. Kreuzer, J. Lepowsky, C. Schweigert.

Budget: €45.000.

Dates: Spring 2004.

String theory in curved backgrounds and boundary conformal field theory

Organizers: H. Grosse, A. Recknagel, V. Schomerus.

Budget: €72.000.

Dates: March-June, 2004.

Many-body quantum theory

Organizers: M. Salmhofer, J. Yngvason.

Budget: €67.500.

Dates: July-December, 2004.

Singularity formation in non-linear evolution equations

Organizers: P.C. Aichelburg, P. Bizon, S. Klainerman.

Budget: €40.500.

Dates: Fall 2004.

Workshop on optimal transportation problems and entropy methods

Organizers: Y. Brenier, F. Otto.

Budget: €13.500.

Dates: Fall 2004.

Part III

Report of the Review Panel

Report of the Review Panel on the Erwin Schrödinger International Institute for Mathematical Physics

November 30th – December 1st 2002

Members of the panel:

Prof. N J Hitchin (Savilian Professor of Geometry, Oxford) *Chairman*
Prof. Dr. R Dijkgraaf (Chair of Mathematical Physics, Amsterdam)
Prof. Dr. J Jost (Director, Max-Planck-Institut for Mathematics in the Sciences, Leipzig)
Prof. N Reshetikhin (Professor of Mathematics, University of California, Berkeley)
Prof. V Rivasseau (Professor of Theoretical Physics, Orsay)

§1. Overview of the Institute

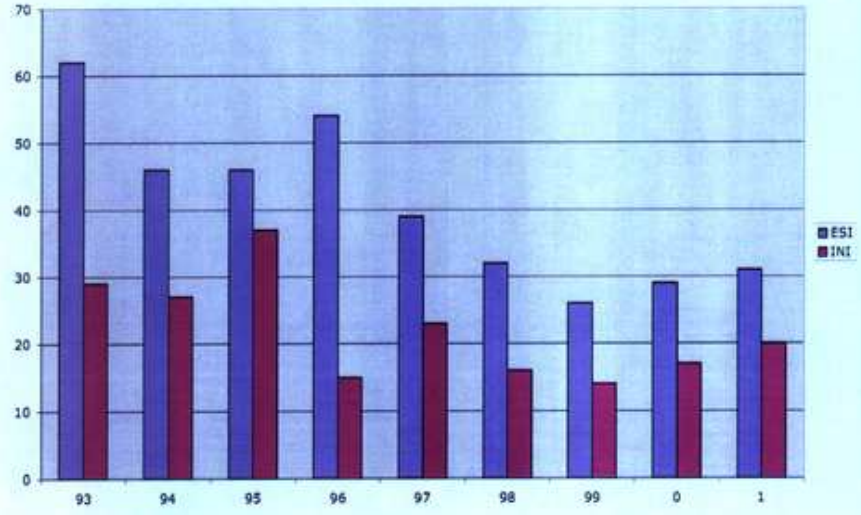
The ESI was founded in the early 1990's to provide "a focal point for both Eastern and Western science and an international platform at the highest level of research". This mission was strongly influenced by the desire to aid the scientific community in the former communist countries of Eastern Europe, with the aim of trying to stem the brain drain from those countries. Its first activities in 1993 attracted some very strong participants but over the next three years its programmes were constrained by the size of the location, adjacent to the last home of Erwin Schrödinger. In 1996 the Institute moved to its present premises, within a 200-year old Catholic seminary whose interior was attractively and innovatively remodelled for its new purpose. At the same time the International Scientific Advisory Board was restructured to include leading international figures with both a high research profile and active knowledge of parallel institutions.

The new Institute, with its capacity of 35 desks, has evolved a method of hosting programmes and visitors which is particularly economical with regard to staffing resources. The Directors and President receive no salary, but benefit from their "shares". (In this respect, the panel acknowledged also the tremendous time and effort which the President and Directors have spent in running the Institute.) The computer system is deliberately kept simple and can be managed without a full-time computing officer. The three secretarial staff handle the needs of the visitors with the minimum of bureaucracy.

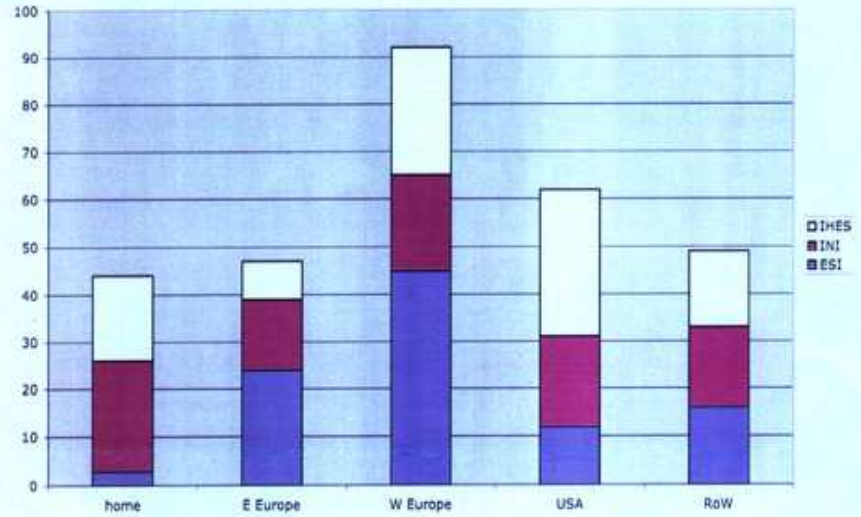
After nearly ten years the ESI has gained a recognized position amongst the research institutes in mathematics and physics in Europe by building upon the scientific tradition of Vienna in the fields of mathematics and physics and the cultural tradition and the regional contacts in Central Eastern Europe. It participates in particular in the postdoctoral EPDI programme which links the two Max Planck Institutes in Germany, the IHES in Paris, the Isaac Newton Institute in Cambridge, and institutes in Warsaw and Spain. For a country of eight million, Austria is clearly competing well at the same level as much larger countries in this area. It is also exposed to the same phenomena, one of

which is the decline of long-term visitors, largely due to social changes. The first graph below illustrates that the ESI has always had a higher proportion of long term visitors than the Isaac Newton Institute but follows the same trend, and in the second we see that having established itself in the same league as the other European Institutes, the visitor profile (for the year 2001) is distinctively weighted more towards Eastern and Western Europe.

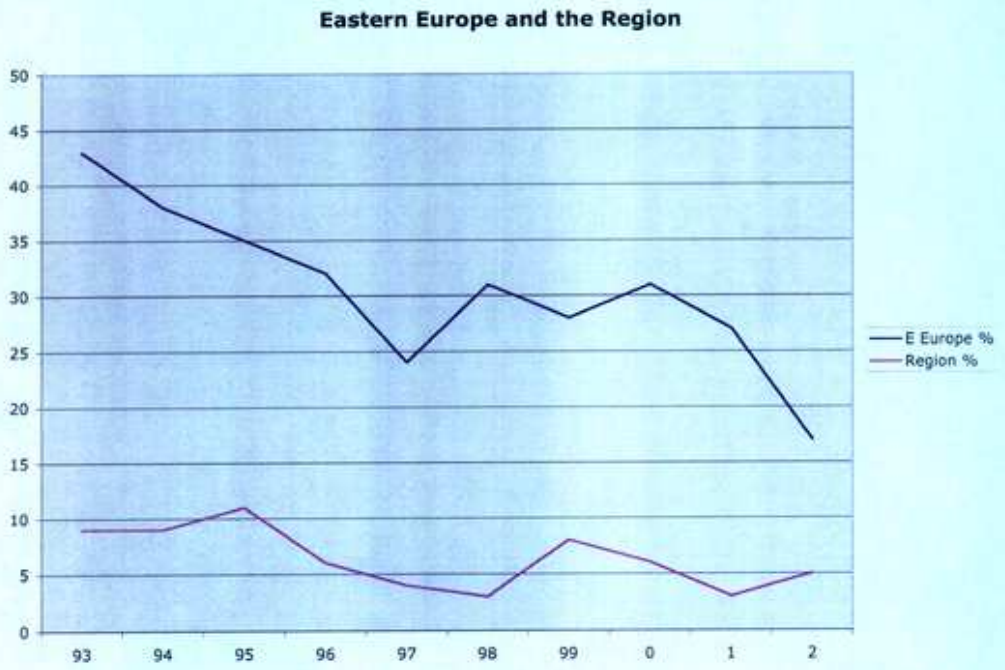
Percentage of long term visitors



Visitor profile



Because of its geographical and historical situation the Institute has attracted over the last nine years a large number of visitors from Eastern Europe. Now as it enters the second phase of its existence, that pattern is changing. The chart below shows the gradual decline in the percentage of visitors from the former communist countries and also the proportion from those nations of Eastern Europe – Hungary, Slovakia, the Czech Republic and Slovenia – which will become new members of the European Union and which belong to the region for which Vienna is a natural focal point.



§2. The Panel's procedures.

The panel members were provided before the visit with the Institute's Scientific Report for the years 1993-2002, together with budget statements for the years 2000 and 2001. They also received while at the Institute synopses of the Advanced Graduate Lecture Series given by Senior Research Fellows Professors Vershik and Onishchik.

During the first morning of the visit, Saturday November 30th 2002, the panel consulted the President and Scientific Directors and Professor Schwermer, the liaison officer to the Austrian Universities. They then made a tour of the premises and talked to the secretarial staff. There followed a consultation with two Senior Fellows, Professors Todorov and Onishchik, with Professor Losik and two programme/workshop organizers Professors Kamber and Garcia-Prada. Over lunch in the common room contact was made with mathematicians and physicists from the local community which was further developed in panel consultations in the afternoon. Representatives in mathematics and physics from the University of Vienna and the Technical University were present as was a graduate student and postdoctoral researcher. After a private session the panel consulted again with the President, Scientific Directors and Professor Schwermer, discussions which continued in a more informal manner over dinner. On the following Sunday morning, Senior Fellow Professor Vershik gave his opinions to the panel.

§3. The programmes

The core activity of the Institute consists of the five large programmes run annually. Most years have at least one programme which can be favourably compared to any such activity in the area worldwide. The key participants have been secured at some stage in the programme, and the topics covered have been at the cutting edge of research in the discipline. To name a few, there are the programmes on Schrödinger operators (1993), noncommutative differential geometry (1995), ergodic theory (1997), spectral geometry (1998), functional analysis (1999), representation theory and algebraic groups (2000), random walks (2001) and developed turbulence (2002). These demonstrate a wide range of subjects covered at the highest possible level.

Every year there are also programmes which perform a very useful function, bringing together a significant proportion of the world experts in a coordinated way. There are ongoing minor commitments such as the Winter School in Differential Geometry and also sporadic events which capitalize on anniversaries of eminent physicists and mathematicians to bring together leaders in the field.

The panel got a good feeling for how the Institute operates by talking to Franz Kamber, the principal organizer of the current programme on foliations. He had initially budgeted for €90,000 but ESI reduced this to €80,000 in direct funding. The resultant gaps were filled by using a mixture of contributions from Directors' shares, the Clay Institute in the USA and the EDGE European network. This achieved a total funding of €100,000. Out of 140 potential participants, 90 came, and without too much management they averaged 10-15 a week which suited the constraints of desk space. Some of the big names in the field such as the Fields Medallist Alain Connes attended, and in order to provide the space for working on actual problems, lectures were restricted to two days a week. Kamber found the facilities offered by the institute ideal for the programme he ran. The panel heard a similar response from Dr Garcia Prada, who ran a workshop within the

programme. He remarked that, thanks to the way the Institute dealt with the activity, it was possibly the easiest workshop he had ever organized.

Programmes are in general planned two years ahead of time, but the Directors' shares allow the possibility to fund activities at short notice. The panel approved of this flexibility, and would like to see it extended, though could not come to agreement on how the distribution of such extra sources of funding would be managed.

§4. The International Advisory Committee

The Advisory Committee plays an essential role in the running of the Institute. It is the quality control mechanism for the scientific content of the programmes and provides input to improve proposals. It can also solicit proposals. During the last two years 50% of the proposals have been rejected through this filtering process, some of them of a good quality. This selectivity is a healthy sign of the demand for the ESI's facilities and the quality of the programmes agreed upon.

Unlike other institutes, the committee does not ask for external referees' reports on the proposals, but relies on the expertise of the members of the committee and their close contacts. It would be a significant extra clerical task if such reports were to be sought, which ESI may not want to take on, but it does mean that currently the balance of the programmes and their content is to a large extent in the hands of the committee.

The panel noted that there did not seem to be a systematic turnover of members of this committee, or well-defined criteria for membership. It had changed significantly in 1996-97 and since then the local participation has been reduced, but for example Professor Lieb had been on the committee since the beginning.

The panel believes that ESI should give more thought to both subject coverage and geographical coverage of the membership of the Advisory Committee. For example, one might put a theoretical physicist on it, an eastern European member, and so on. Possibly it should be enlarged. If the committee is to initiate research programmes it is essential that new ideas are fed into it by changing its membership in a regular fashion.

§5. Operation of the Institute

The panel noted that the hotel accommodation offered was of a high standard, but that visitors who wished to pay less of their daily allowance on housing were aided by the secretarial staff to find something suitable – a number of standard locations were used. Although the Franz Josef Hotel was some distance away, access by tram was easy. Since travel is not covered by the institute, payments to visiting scientists are relatively straightforward. The per diem payment is at the moment €75, comparable to that paid at the Isaac Newton Institute. Visitors when they arrive can register, receive their computer

account and have their photograph taken quickly, as the panel experienced. Even when a workshop was beginning, the secretaries told the panel that the numbers were such that they could be easily managed.

The design of the building was very effective as well as being of a high architectural standard. Some remarks were made about the lack of soundproofing between the offices but the computers in the corridor and the chairs and blackboards outside offered ample opportunities for interaction amongst the visitors. The physics library is very close and the mathematics one a short walk away. Facilities for lunch are available in restaurants nearby. One participant told the panel that the size of the city of Vienna was also ideal for a congenial stay.

The panel noted that computer-related problems are dealt with by Dr Cap, who has an office in the building, and for his services he receives a small "share". One panel member remarked that the introductory notes for visitors on the webpage, in particular for local travel, needed updating. The efficient operation of the Institute owes much to the chosen size of the facilities and the number of people within it at any given time. Any increase in size or scope would be likely to require additional fulltime staff.

§6. Organizational structure

The organization of the Institute under the aegis of the Erwin Schrödinger Society appears to function well. While having a symbiotic relationship with the University of Vienna, the independence of the Institute was felt by the panel to be an important feature, and everything should be done to preserve this.

§7. Senior Fellows

The longer term Senior Fellows are now required to give advanced graduate lectures. The panel was given synopses of two of these: *Real forms and representations* by Arkadij Onishchik and *Measure theoretical constructions and its applications to representation theory, dynamical systems and combinatorics* by A M Vershik. The panel spoke to a student who had attended one of the courses which he had appreciated. The attendance of 10-15 for these is normal at this level. Professor Vershik told the panel that one local student had been writing up notes of the lectures and that this would form the basis of a published version. There was a clear mutual benefit in this activity.

The new form of Senior Fellow serves the local graduate students well but it should not be the only format – the ability to give courses in relevant fields for the Vienna students might narrow too far the choice of candidate. The presence of a brilliant researcher for faculty and visitors benefits Austrian mathematics and physics equally well.

§8. Interaction with the local community

At an everyday level, the ESI interacts with the University of Vienna by sharing facilities – libraries, lecture rooms and computing expertise for example. As far as the panel could see this worked well.

The panel's discussions with members of the local community brought out the links and benefits beyond the tangible contribution of lectures from the Senior Fellows. Since it is normal to have a local organizer for each programme, there is a clear benefit not only for that person's research but also his students in the area. Direct contact with visitors and participation in discussions can advance an individual's research considerably. From the Technical University, the panel was told that, in a background where there is little tradition or funding for weekly seminars, the activities of the ESI have a great impact. Workshops were thought to be particularly important, not just for Viennese scientists but in Austria in general. Some of the local representatives thought that a little more attention could be paid to advance publicity for lectures at the ESI, especially last-minute changes. The panel was informed by the Directors of the mechanisms in place at the moment to do that – notices, e-mail listings etc. Some of the local physicists also conveyed to the panel their feeling that the Institute's programmes were biased too far towards mathematics.

One interaction with the community which the panel thought could be enacted on a regular basis is the notion of an introductory workshop at the beginning of every major programme. This would offer surveys of the main themes within the coming programme for graduate students and workers in adjacent disciplines. Similar activities are carried out in Warwick before a year-long programme and at MSRI.

An important feature of the relationship of the institute with its neighbours is the external perception of the high academic standing of the institute. If it is not viewed as a place where there are good scientists, its influence will not be felt, and the resources it takes may be resented. It is important then, at both an international and national level, that the high reputation which it now has should be maintained.

As with most Departments, retirements from senior positions in Vienna will occur during the next few years. The panel believes that the presence of the ESI could be used as leverage to attract high-profile individuals to fill the positions, and it will be possible also to use the Institute and its visitors programme to support the new research directions which the appointee might bring along. The Institute could then become a vehicle for broadening and strengthening the local expertise which in turn would have a beneficial effect on the range of programmes put on during the second decade of its existence. A longterm presence of excellent researchers at the highest international level in Vienna is necessary for the ESI to continue and conversely the Institute can help to preserve that.

§9. Interaction with the region

The Institute was founded in an an era of uncertainty in Eastern Europe when the very continuation of academic science in some countries was under threat. The next decade will see a stabilization within the immediate region and an increase of political ties between countries such as the Czech Republic, Slovakia, Slovenia and Hungary within the European Union. These four countries have a population of 27 million and a current total GDP more than that of Austria, and set to expand rapidly in the near future. An opportunity presents itself for the ESI to become a natural focus for mathematics and physics within this larger context.

To emphasize this is not to suggest that the ESI should exclusively depend on the immediate region, simply to point out that there will be more opportunities within the near future to capitalize on the geographical position of Vienna and the established status of the Institute.

§10. Conclusions

The panel was impressed with the overall scientific standing of the Erwin Schrödinger Institute and earnestly hopes that appropriate funding, taking account of any forthcoming changes in outgoings, will continue in order to maintain and advance the achievements of the first ten years. It operates currently at a capacity which enables it to function very efficiently. Centring the scope of its activities on mathematical physics and related mathematics, without excluding theoretical physics, seems to us optimal for ESI. This reflects both the origins of the institute and also its ability to attract world-class experts from a wide range of countries, and especially those of Eastern Europe. Keeping this focus enables the Institute to operate compatibly with its size, budget and surroundings, though it could be open to a moderate diversification should the opportunity arise.

§11. Recommendations

Below we list some specific recommendations which arose out of the panel's consultations:

1. Allow the possibility of a change of emphasis in the Advisory Board when retirements come up. At the moment, the scientific emphasis is perhaps too much oriented towards purely mathematical topics at the expense of the representation of new areas of physics where mathematical tools are already having, or potentially will have, a large impact.

2. The new system for a Senior Fellow serves some of the needs of local graduate students but it should not be the only format – the presence of a brilliant

researcher in the midst of faculty and visitors benefits Austrian mathematics and physics equally well.

3. Introductory survey lectures could be used systematically to introduce the subject to graduate students, faculty members and those in the parallel programme.

4. Every effort should be made to develop the ESI's role as a Central European research institute, as political ties increase in the area, and funding opportunities in the region expand.

5. The presence of the ESI should be used as leverage to attract high-profile professors to fill vacant positions, and the Institute and its visitors programme used to support, if appropriate, new research directions from the appointee.

6. Maintain and improve communications with the Viennese community and beyond. Advertise the activities internationally and show beyond the immediate academic community how the ESI makes a positive contribution to the image of Austrian science.

7. A physicist as well as a mathematician should be used to liaise with the Universities, compensated for his or her work by a "share".

8. The funding body should consider an appropriate budget increase to compensate for inflation over the past years and to allow additional flexibility, in particular to respond to new scientific developments of direct interest to the partners at the Viennese Universities.

17 Feb 2003

Appendix A: History

The foundational period of the Erwin Schrödinger Institute

In August of 1990 Alexander Vinogradov, Moscow, sent a letter to Peter Michor, Vienna, with the proposal to set up an institute devoted to mathematics and physics in Vienna. This proposal had been preceded by discussions between Vinogradov and Michor on the preservation of the scientific community in the Eastern European countries in the aftermath of the fall of the communist governments in these countries. The entire region was threatened with a huge brain drain involving many of these countries' best scientists.

Setting up an institution on the interface between mathematics and physics in Vienna was seen as a potentially valuable contribution at this time of crisis: Based on the cultural and scientific tradition in Vienna, especially in the field of mathematical physics, a new institute based in Vienna could provide a focal point for both Eastern and Western science and an international platform at the highest level of research in the field of mathematical physics.

This initiative was warmly welcome by Walter Thirring, Vienna. In a letter to the Minister of Science and Research, Erhard Busek, dated October 18, 1990, Thirring proposed to establish an international research institute in Vienna, devoted to mathematical physics with the name 'Erwin Schrödinger Institute for Mathematical Physics'. Thirring's proposal immediately won the support of eminent scientists all over the world, and Busek favorably responded in December 2000. A window of opportunity to realize this dream was opened, complemented by the Government's political intention to set up a major research institution in Austria. Michor again became active in collecting first ideas laid out in a memorandum of December this year (see *Gedanken zum 'Erwin Schrödinger Institute for Mathematical Physics'* on page 153).

An intense phase of preparation for the start-up of the institute began during the first half of 1991, resulting in the organisation of a workshop 'Interfaces between Mathematics and Physics' in May. The members of the workshop constituted an International Scientific Council and elected Thirring as chair. (For the minutes of this meeting see *Report on the Workshop: Interfaces between Mathematics and Physics, 1991* on page 155). Subsequently, an in-depth feasibility study was commissioned by the Minister and presented by Thirring, Heide Narnhofer and Michor in autumn 1991 (see *Erwin Schrödinger International Institute for Mathematical Physics, Vertiefungsstudie* on page 159). A decisive step on the level of science policy in December 1991 was initiated by the positive recommendation of the Austrian Council for Science and Research, the science advisory committee to the minister, to set up the institute.

During all of 1991 a search took place for an appropriate accommodation of the new institute, taking into account locational,financial and organizational constraints.

In March 1992 a second workshop 'Interfaces between Mathematics and Physics', chaired by Julius Wess, took place with 140 participants from 17 countries. This occasion was marked by the 1st Meeting of the newly established International Scientific Advisory Committee. (see *Conference on Interfaces between Mathematics and Physics*, in the beginning of this report). The first ESI-Newsletter was issued in April.

The society 'Internationales Erwin Schrödinger Institut für Mathematische Physik' was officially founded in April 1992, and on May 27 the constitutional general assembly of this society elected Thirring as its president (with Wess, Michor and Reiter as deputies) and took the formal decision to set up a research institute under the legal framework of the society. Busek confirmed this in writing on April 24 and the ministry subsequently allocated first funds to the institute. The physical location and level of

funding of the institute were still unresolved at this stage.

The great international support and a formidable team work among the people involved in the foundation of the ESI once again became visible when the conference '75 Years of Radon Transform' was held in Vienna in September 1992 as a first widely recognized activity of the institute (see *Conference '75 years of Radon transform'* on page 13).

With the beginning of 1993 it became all but clear that the frame of the institute as envisaged in the feasibility study of 1991 had to be reduced by a factor of one third. Initial disappointment was quickly overcome when an appropriate location for the institute was found near the Mathematics and Physics Institutes of the University of Vienna, in the house where Erwin Schrödinger spent his last years. The institute started to operate in January 1993 with three scientific programs (two in physics, one in mathematics) and about 40 visitors from 10 countries; Thirring acted as scientific director and Michor as executive director. In March the institute became visible with the first ESI-preprint published.

The official opening of the International Erwin Schrödinger Institute for Mathematical Physics took place on April 20, 1993, at Pasteurgasse 4/7 and 6/7 in Vienna's 9th district under the auspices of Vice Chancellor and Minister for Science and Research, Erhard Busek (see on page 15).

From the very beginnings of the planning for ESI a basic set of conceptual and organizational corner stones were widely accepted among all people involved: cross-fertilization of mathematics and physics as the institutes scientific rationale, international character of the institute, highest scientific quality, program orientation of its activities and invitation of leading experts, flat organizational and hierarchical structure among management and visitors, and no permanent positions.

After slightly more than two years, intense discussions about hopes, aims and philosophy concerning the establishment of this new institute, a dream had attained reality. ESI quickly made its way into the top league of mathematical physics institutes worldwide, and the institute's attractiveness as a place to work in Vienna established itself astonishingly fast within the mathematics and physics scientific communities.

Wolfgang Reiter
Bundesministerium für Bildung, Wissenschaft und Kunst
September 9, 2002

Gedanken zum 'Erwin Schrödinger Institute for Mathematical Physics'

1. Vorgeschichte. Seit dem Jahr 1985 halte ich mit Ivan Kolař von der tschechoslowakischen Akademie der Wissenschaften, Abteilung Brünn des Instituts für Mathematik, ein Seminar über Differentialgeometrie ab, das einmal im Monat tagt, vor dem Fall des eisernen Vorhangs fast ausschließlich in Brünn, danach häufig in Wien. Unterstützt wurde ich durch einen Dienstpaß. Durch dieses Seminar kam ich engen Kontakt mit den besten Differentialgeometern des Ostblocks, da ich für sie so etwas wie einen regelmäßigen Westkontakt darstellte, und ich war geladener Gast bei vielen Konferenzen im Ostblock. Dabei habe ich auch eine Reihe von russischen Mathematikern kennengelernt, darunter A. M. Vinogradov, dessen Arbeiten mir vorher schon aufgefallen waren. Er trat nun im September 1990 mit der Idee an mich heran, in Österreich ein Forschungsinstitut zu gründen, das auf dem Gebiet nichtlinearer Phänomene internationale Zusammenarbeit mit besonderer Betonung der Ost- West- Zusammenarbeit und interdisziplinäre Zusammenarbeit zwischen theoretischer Mathematik und theoretischer Physik fördern sollte. Untermauert war diese Idee durch sein Manifest, ein fundiertes und zukunftsweisendes Konzept.

Professor Walter Thirring hat diese Idee sehr gut gefunden und sich gleich aktiv dafür eingesetzt. Vinogradov hat Wissenschafter aus fast allen europäischen Ländern angeschrieben und um Stellungnahmen gebeten. Begonnen hat er damit in Rußland, daher sind diese Stellungnahmen die ersten, die eintreffen. Besonders hervorzuheben ist die von Vladimir Drinfeld, Fields-Medaillenträger 1990.

2. Warum so ein Institut in Österreich sein soll. Während der langen Zeit des kalten Krieges hat Österreich eine Mittlerrolle innegehabt und daher einen guten Ruf in Ost und West. Geographisch ragt es ziemlich weit nach Osten, ist also durchaus geeignet dafür.

3. Was hat Österreich davon? Da dies ein rein theoretisches Institut sein soll, ist es verglichen mit anderen Großforschungsprojekten sehr billig. Die theoretischen Wissenschaften sind (waren) im ehemaligen Ostblock sehr gut entwickelt, gerade wegen der materiellen und instrumentellen Beschränkungen anderer Wissenschaften und der relativen Unabhängigkeit haben sie die besten Talente angezogen. Der Osten ist (oder war bis vor kurzer Zeit) dem Westen vielleicht nur auf diesem Gebiet (und dem Schachspiel) mindestens ebenbürtig.

Zur Zeit findet gerade eine große Emigrationswelle statt, von der wieder einmal die USA am meisten profitieren. Dieses Institut, wenn es rasch verwirklicht wird, könnte erstklassige Kräfte befristet oder auch länger an sich binden, und in längerer Folge in ihren Heimatländern und in Europa halten.

Der Verzicht auf viele permanente Stellen könnte das Institut lange lebendig halten und und ein anregendes wissenschaftliches Diskussionsklima in Österreich auf dem zur Zeit äußerst fruchtbaren Gebiet zwischen Mathematik und Physik schaffen. Am Rande: Drei der 4 in Kyoto vergebenen Fields-Medaillen gehören dem Gebiet der Mathematischen Physik an. Fields Medaillen werden nur alle 4 Jahre am internationalen Kongreß für Mathematik vergeben, früher 2, dann 3, seit kurzem 4. Sie sind also etwas exklusiver als Nobelpreise.

Der weltweite wissenschaftliche Widerhall, der von diesem Institut zu erwarten wäre, ist für Österreich zu diesem Preis/Leistungsverhältnis höchstens noch auf dem Gebiet der klassischen Musik zu erwarten.

4. Warum gerade Mathematische Physik? Wie schon im Abschnitt 3 ausgeführt, sind die theoretischen Fächer und besonders ihre entwickeltsten Gebiete Mathematik und Physik das beste, was der Osten zu bieten hat. Darüber hinaus sind theoretische Fächer preiswert und haben (allerdings ziemlich langfristig) einen ungeheuren Einfluß auf Wissenschaft, Technik, Gesellschaft und philosophische Weltsicht. Die Halbwertszeit ihrer Erkenntnisse liegt (besonders in der Mathematik) weit über der anderer Wissenschaften.

5. Wie paßt das Institut in die österreichische Wissenschaftslandschaft? Wenn ich ehrlich bin, finde ich die österreichische Mathematik und etwa weniger auch die Physik doch ziemlich provinziell: auf internationalen Tagungen schwach vertreten, in renommierten Zeitschriften kaum aufscheinend. Dies hat mehrere Gründe. Zu viele und zu kleine Institute, die besten davon mit Lehre überlastet und unter sehr beengten Umständen arbeitend, relativ fossile Hierarchien und wenig Leistungsanreiz. Allerdings muß man bedenken, daß Österreich doch relativ klein ist und etwa nur ca. 200 Universitätsmathematiker hat.

Herausragt dabei doch die Schule der mathematischen Physik, die Professor Thirring begründet hat und die durchaus mit den besten der Welt konkurrieren kann. Ein bedeutender Mathematiker mit starkem Interesse an mathematischer Physik ist Otthmar Loos in Innsbruck. Dieses Institut könnte also genügend Fundament und Unterbau in Österreich finden, um florieren zu können. Der größte positive Nutzen für die österreichische Wissenschaft wäre allerdings zu erwarten, wenn dieses Institut nicht allzuweit von den Universitätsinstituten entfernt wäre, die immer noch die Mehrzahl der begabtesten Studenten Österreichs an sich binden können, nämlich den fachlich verwandten der Universität Wien. Vorträge, Symposien und Aktivitäten am Institut könnten sehr inspirierend auf den wissenschaftlichen Nachwuchs wirken.

6. Ideen zur wissenschaftlichen Organisation. Man sollte zuerst die Organisation von gut funktionierenden ähnlichen Instituten in Augenschein nehmen, wie:

- Institute of Advanced Studies in Princeton,
- Institute des Hautes Etudes Scientifiques in Bures-sur-Yvette,
- Mathematical Science Research Institute in Berkeley (gegründet vor ca 5 Jahren)

- Max-Planck-Institut für Mathematik in Bonn
- Forschungsinstitut für Mathematik an der ETH Zürich
- SISSA in Triest.
- Mathematics Institute an der University of Warwick/UK

In Gründung befindet sich zur Zeit auch das 'Isaac Newton Institute of Mathematical Sciences" in Cambridge/UK unter Atiyah, und ein ähnliches Institut in China, dessen Initiator und Direktor S. S. Chern ist, der Gründer des Instituts in Berkeley.

Eine bewährte Methode, die von Chern in Berkeley eingeführt wurde, ist die folgende: Jedes Jahr wird ein gewisses Thema zum zentralen erklärt und ein führender Wissenschaftler auf diesem Gebiet eingeladen, als Vorsitzender die weiteren Einzuladenden zu bestimmen und für dieses Jahr einen Gutteil des Betriebes zu organisieren. Z. B. organisiert Graeme Segal aus Oxford (jetzt Cambridge) in Berkeley das kommende Jahr in Berkeley, das der Quantenfeldtheorie gewidmet ist.

Man kann damit rechnen daß in ein renommiertes Institut auch viele Gäste mit geringer Unterstützung im Rahmen ihres 'sabbatical years' kommen würden. Das oben angeführte Institut in Warwick (wo auch ein Österreicher, Klaus Schmidt, wirkt, lebt davon).

7. Gedanken zur räumlichen Organisation. Das geplante Institut sollte einen ansprechenden (nicht üppigen) Rahmen in netter Umgebung haben, etwa 30 Arbeitszimmer (in der Regel für 2 Personen, um die Kontaktfreudigkeit zu heben), zwei bis drei Seminarräume mit guten Tafeln, Grundaustattung mit PC, einige gute 'work stations', alles vernetzt und mit Anschluß and den österreichischen Computerverbund. Sehr wichtig wäre ein Gästehaus, zum Teil wie ein Hotel, zum Teil Zimmer mit Kochnischen und kleine Appartments (viele Gäste würden mit Familie kommen).

Ein zentraler Punkt ist die Bibliothek: sie sollte weiträumig und relativ vollständig sein, besonders da im Osten Literaturzugriff schwierig ist. Ein Vorschlag, der vielleicht meiner Betriebsblindheit entspringt, ist, die Bibliothek des Instituts für Mathematik, die gut bestückt aber äußerst beengt ist, zur Bibliothek dieses Instituts auszubauen und mit der Universität gemeinsam zu nutzen, als Zentralbibliothek für Mathematik.

8. Unrealistische Vision. Dieses Institut zusammen mit den Instituten für theoretische Physik, theoretische Chemie und Mathematik der Universität Wien und einer exzellenten Bibliothek unter einem Dach oder sehr nahe beieinander.

Peter W. Michor
Universität Wien
31. Dezember 1990

Report on the Workshop: Interfaces between Mathematics and Physics, Vienna, May 22 – 23, 1991

This informal report was written on June 13, 1991 and amended on August 5, 1991 (including amendments by P. Budinich).

Participants

P. Budinich (SISSA Trieste)
A. Connes (College de France – IHES)
J. Fröhlich (ETH Zürich)
L. M. Faddeev (Steklov Institute, Leningrad)
A. Galindo (Universidad Complutense, Madrid)
G. Marmo (Università di Napoli)
V. Souček (University of Prague)
A. Trautman (University of Warsaw)
I. Todorov (University of Sofia)
A. M. Vinogradov (University of Moscow)
J. Wess (Universität München)
W. Reiter (Austrian Ministry of Science)
W. Thirring (Universität Wien)
P. Michor (Universität Wien)
H. Narnhofer (Universität Wien)

Wednesday morning. General and free discussion on organization, comparison of different research institutes.

Minister Busek greeted the participants: Austria was on the border of free Europe, now it is in the middle. Austria is willing to create a research institution of international impact, but scientists should say what they want and why. Some side conditions already came to attention: near a University, near the libraries, accommodation possibilities.

It was stressed very much, that the ESI should be near a University to enable contacts, especially for graduate students (everybody). To build a library can take 15 years (Budinich). The MSRI in Berkeley worked very well as long as it was located on the campus, now it is too far away (Wess). It also has a mistake in concept: there is scientific circus all the time, visitors should not be viewed as consumers of a pre packed scientific program, the institute in Santa Barbara is better (Fröhlich).

The ESI should also offer summer schools and conferences (Wess). In the Center in Trieste which is aimed towards developing countries the following system is applied: 2 weeks of course, 1 week of workshop, 1 week of a topical meeting where the best participants of the foregoing weeks also take part. (Budinich).

Connes: Working conditions and contact are very important. Counter examples are: IAS in Princeton, in former times the cafeteria was small and one could meet, now it is luxurious and split into small isolated tables where people tend to avoid contacts. It is too big, permanent members devote a lot of energy to choose visitors and post docs, which then come and do not have many contacts. In the MSRI (say: Misery) in Berkeley there is no lunch, doors are closed, and even the view is distracting. Also MIT is a place with closed doors. Good examples are IHES, in Harvard the building because all is intertwined, also Leningrad. The design of the building should encourage contact.

Trautman: The topic is well chosen, see Atiyah – Witten collaboration and the finding of exotic differential structures on $\mathbb{R}^4$. The interaction between mathematics and physics is traditionally more intense in England and USA than in central Europe. There is a huge brain drain towards USA. An axis Vienna–Trieste could help to slow this. The political changes in the east had a lot to do with interactions between people; Poland and Hungary came first where people could travel relatively free even before the changes. Mathematics and Physics form a small community, but a very influential one: now in Poland many rectors, also 3 in the senate (from 100). The greatest theoretical physicist of Poland, Marian Smolochovsky, was educated in Vienna and moved later to Poland, and Poland hopes for similar collaboration in the future.

Thirring: There are difficulties in the East, with libraries, budget, publications. What are the most urgent problems?

Todorov: It is not so important to educate students from the east in modern science, it is more important to preserve groups which are already good, but are in danger. Publication is now not a problem, there are no page charges in western Europe. One should help younger scientists to survive in their own places. Bulgaria and USSR feel the danger of brain drain most. Cuts in budget for academic institutions, in libraries; cut off from all western publications now. Cuts in personal, lately 10%, soon again 10%, more teaching. It is easy to destroy a scientific group but hard to recover, compare with the Nazi regime in Germany, it has not fully recovered till today. It is important to start ESI as soon as possible and work in scientific directions that exist in eastern Europe. Availability of part time positions or temporary positions could help a lot.

Fröhlich: If people feel insecure, it will not help to invite them. Only if an excellent institution is there it could keep people in the neighborhood. It is less important to discuss scientific directions, more to get the best people as condensation center. The attraction should be scientific, not economic.

Wess: There is need for an institute of mathematical physics also in the West. It should be excellent in any case, otherwise it might be used just as a railway station to USA.

Vinogradov: Some political aspects in science: the ESI should be different from existing institutes, which tend to foster short wave kind of science, especially in mathematics; physics is in certain aspect more long wave science, because there is always nature pointing to the weak points of understanding. ESI should try to create a new type of scientist who combines mathematics and physics again in his thinking and is a long wave scientist: short wave science produces solvers of posed problems, not creators of new concepts. Sophus Lie could never have won a fields medal. In SU there exists a

tradition of long wave science and one should try to keep, to keep some of best intellects here, although it is difficult to stop emigration. One should also organize a circulation of the best graduate students through Europe. (Idea of long wave science met approval)

MARMO: Picture of the situation in Europe is necessary of all the attempts to hinder emigration; one should compare with other institutes, which compete for the same money. In Lecce Calogero is creating a new institute of nonlinear nuclear physics which is financed by the local government. In Torino Regge and Rasetti have the Institute of Scientific Interactions, which centers on solid state physics, organizes 6 months programs with 6-8 people and which will not enlarge. There is also the proposal for a European Institute for nuclear physics in Italy or in Copenhagen. One should try to push the proposal of the ESI as soon as possible. Post doc positions are very important, it is easier to keep young people from emigrating.

BUDINICH: Center of Excellence is very important. The ICTP and SISSA in Trieste would be willing to establish collaboration. One should study instruments to hinder the brain drain: At SISSA (Trieste) a new kind of professor is created by a law: it can ask the minister to appoint a visiting professor for five years who has to stay in the lab only for 4 months per year, so he can keep contact with home in east and help there. Also some Italians from US can come back with this instrument and also SU → US → Italy → SU. A similar position in ESI could be helpful for the East.

TODOROV: Invitation of a renowned institute would enhance the status at home.

SOUČEK: In CSFR the support for universities has been cut by 20%, some people will loose jobs: how to find a place for talented young people: the young generation is in danger at this time.

FRÖHLICH: Now there is a good chance to get good people for part time. Strong connection with University is important, but there are mixed feelings about it in Zürich: J. Moser and Fröhlich are responsible for the visitor program of the ETH, there are a lot of visitors, but to organize this is too much work, especially since they have full duties at university and the administration is too heavy. Organizer should be free from the University, especially from the administration there, teach only every second semester. There is the general idea to create European network of post doc positions, (Atiyah proposed it, Wess). So applicant can be chosen centrally (no clear scheme yet) for three years, say, and then circulate through European institutes. To choose them is hard work, if it is only one year they have to apply immediately for the next year, the effect is low.

GALINDO: Enthusiastic support for the project of ESI, an institute like this is necessary, center of excellence also. Spain will be interested in ties with the institute, send people and receive people from there.

MARMO: CFNR will sign a contract with ESI, paying people to visit there and receive people from there. Also the Director of the University of Napoli will sign a contract, but ESI should have 'international' in its title for legal reasons in Italy.

WESS: Germany is occupied with reunification, a strong lobby is necessary there, Volkswagen Stiftung is reluctant to support long term projects, so no direct financial support now.

Comparison with other institutes. FRÖHLICH: IHES in Bures (he is external member of scientific council) This is a meeting place for mathematics and for physics. In the beginning only some excellent scientists there, visitors only to assist the members, best time when Grothendieck was there, ideal concept but not realistic, especially not for ESI. Now 6 permanent members, character has changed, more meeting place. Support staff is quite big: 6 secretaries, one for the director, one receiving visitors, 4 typing. 1 chief of administration, 2 accountants, 1 for printing, 1 driver, 1 housing supervisor, 1 computer support (for sparc cluster), 1 for the library. The library is bad. The original idea was only to buy the good books. This has worked out badly, since the change to find is low; one is not even looking. Connes). Scientist should not be bothered, need help to find apartments, to send children to school, need help with visa regulations. There is the 'comité scientifique', containing all permanent members, the acting director, some outsiders, not more than permanent members. Then there is the 'conseil d'administration', not containing the permanent members, but the directors and representatives from money givers. Money comes 75% from France, then from UK, Germany, Italy, Switzerland, Japan, etc.; but these countries want profit so there are visitors sometimes, which do not fit scientifically, only to repay the financial support. Outside money is not reliable, makes the project unstable. The director is full time, very (too) powerful, not supposed to do research. Relic from the private foundation time. (Director is above science, impossible to choose him, much better to have a pair of directors, scientific, and administrative, Connes).

CONNES: IAS in Princeton: The permanent members there devote a lot of time to selecting the post docs, but these later do not interact a lot, they a left alone, and there is a lot of tension between them. There are different ideas about work. In the US people have to produce results quickly, so they tend to follow general fashions and shift constantly according to the fashion. There seems to be a cultural difference between Europe and US. In France it is still possible for a scientist to do some work which goes against fashion. For the the ESI you should not follow the scheme of Princeton.

TRAUTMAN: Banach Center in Warsaw. It was meant as means for cooperation between Eastern countries only, fortunately it worked out otherwise. There is no permanent staff, the center organizes semesters devoted to special topics. Visitors come as lecturers or participants. A semester works reasonably well when it is thought out well. The host is the academy, and the idea is similar (and earlier) to that of the MSRI in Berkeley. It should not be taken as a model.

WESS: Max Planck institutes have an evaluation board meeting once a year, this has lot of weight on the finance. The Max Planck Institute for Mathematics in Bonn has only 1 or two permanent members. One should at least start with few permanent positions. There is also a new Sonderforschungsbereich in Berlin.

BUDINICH: The ICTP in Trieste is centered around the director, A. Salam, the faculty is 3–4 permanent members, scientific council does not discuss science, mainly administration. The ICTP devotes a lot of activity to courses and workshops for participants from developing countries. SISSA in Trieste is organizing courses, is subject to the laws regulating universities in Italy but with larger autonomy and with some special privileges to recruit foreign visitors.

FRÖHLICH: There is also the 'Forschungsinstitut Mathematik' at the ETH and a smaller scale Physics institute which he is heading. These are completely integrated into ETH, which has disadvantages. More independence is essential. The organizers do not get enough scientific profit, they only have a lot of work. The organizers should rotate.

For The ESI: Not all local people should be at all time on the board, but local people should have more weight than outsiders.

MARMO: Impact from outside people should be assured.

BUDGET OF LIBRARY: Thirring ATS 5.000.000 as for Zentralbibliothek of Physics? Marmo: Department of Physics in Napoli has the same. Budinich: Center has ATS 10.000.000 per year, more subjects like biology, earth sciences, etc.

FINANCE and the question of national versus international money: one should not expect more than 20% of foreign money, even IHES has 75% of French money. A lot of foreign money makes the project unstable and prevents long range planning, which is essential to the quality of the project. A good idea is to cooperate in the European network of post docs proposed by Atiyah and to get international money in this way.

Wednesday afternoon, scientific discussion. FADDEEV: Mathematical Physics is synthetic, it is a combination of different kinds of thinking, one should start with connections between Mathematics and Physics.

Connes proposes a 'tour de table'.

WESS: what is the aim of the discussion? To select a small number of topics (Connes), the program of the ESI for the next year (Thirring).

CONNES: He recently changed minds on closed strings, which do gravity in the target space. There seems to be a close connection with Waldhausen algebraic K-theory, which tries to understand the homotopy of diffeomorphism groups of manifolds. String theory could lead to a better understanding of Waldhausen K-theory, but the profit of Physics might be small. Constructive Quantum field theory recently underwent developments leading to cohomological thinking, to cyclic cohomology and Floer cohomology. The prize to be paid in analysis is tremendous (it is very difficult), the profit for physics will be small. The combination between quantum groups and non commutative differential geometry could have an impact on Physics. A well posed problem is to construct the Chern-Weil homomorphism for principal bundles with structure group a quantum group. Do not forget functional analysis, it was the original root for knot invariants (Jones), 3-manifold theory, non commutative differential geometry. It is part of the basic foundations of quantum mechanics, although the theory of Banach spaces probably became sterile. Do not give up the long range point of view: Jones was occupied in isolation for four years without visible results before he found his polynomial, for which he got the Fields medal.

FRÖHLICH: He grew up when Mathematics and Physics were separated, it was not a healthy situation. Mathematical Physics is not a field by itself, it needs input from both Mathematics and Physics and tries to make an impact back to the two fields. It is great, but its vitality depends on open communication channels. Particle Physics is the main source of inspiration for Mathematical Physics, but it is in a confusing state just now, it is better to listen to condensed matter physics just now. Pay attention to nonlinear quantum optics. Looking at the quantum Hall effect led me in 1985 to new insights.

SOUČEK: Twistor theory is very important, there can be even higher dimensional analogues.

TODOROV: Applications of non commutative differential geometry as developed by Alain Connes, Michel Dubois-Violette, Kerner, Coqueraux. They lead to more economical theories than the grand unified theory. Low dimensional quantum field theory models are related to quantum groups, see the chain: quantum Hall effect to Chern-Simons type of theory to completely integrable models to quantum groups by deformation.

FADDEEV: Mathematical Physics is not a proper field in a certain sense. It is still well defined, but since it is an interface, its contents also shift with time; nowadays it does not contain Maxwells equations any more - they are ripe. The division between Mathematics and Physics is not a happy one, where does quantization belong to? It is part of non commutative differential geometry and deformation theory and quantizations is an important and open problem. Not so much for theoretical physicists, who are happy if they know how to write the Schrödinger equation. In opposition to Fröhlich he finds that particle physics should be looked at, since we want to understand nature, this is possible only from the fundamentals, and particle physics is the beginning of the study of matter, the fundamentals for us. In a certain sense theoretical physics is trying to use as little mathematics as possible, and mathematical physics is trying to use as much as possible.

GALINDO: Pay attention to fundamental theories, one should also know how to compute, but pay also attention to non perturbative aspects.

TRAUTMAN: Striking results coming from the interaction between Mathematics and Physics in the past: study of instantons, Yang Mills equations, via twistor theory showed that confinement in Physics did not work as expected, but it led via moduli space theory to exotic differential structures on $\mathbb{R}^4$. For the future he sees work to be done in classical differential geometry, interest in global Lorentzian geometry, Cauchy-Riemann structure, optical structures, spinors. Also the spectrum of the Dirac operator is not so well studied.

MARMO: Mathematical Physics is an interface between the two fields Mathematics and Physics, so it gets redefined from time to time. Open questions are in spin statistics, see the quantum Hall effect. The general problem of quantization is still open, quantum mechanics cannot be the ultimate theory, because its fundamentals are not understood. Constrained theory in quantization and representation theory of infinite dimensional algebras will be important.

WESS: In former times one tried to understand nature by using small schemes. Then came periods with new physics, which helped to develop mathematics; now it is hard to find physics without being guided by mathematics already. Field theory = physics. In particle physics one does not even understand the model. Open problems: anomalies, supersymmetries, path integrals, deformation concepts, quantum groups.

THIRRING: In addition to the challenge to find a self contained quantum field theory, theoretical physics has to to explain concrete experiments in physics, and this explanation has to go beyond perturbation theory. But also long standing fundamental problems are still open: for instance mathematical physics has helped to understand stability (this turned out to be a first step for constructing dynamics for an infinite system), one of the fundaments of statistical physics. But a complete understanding of irreversibility and of the approach to equilibrium, the passage from microphysics to macrophysics, is still missing.

VINOGRADOV: Concrete proposals. 1. Algebraic geometry is the study of algebraic equations, but there is also the notion of an algebraic variety for nonlinear partial differential equations called diffiety, more complicated then algebraic geometry, having a lot of geometrical structures. See the chains: differential calculus to algebraic version of it to quantized calculus; higher symmetries of partial differential equations to quantized vector fields to conservation laws; characteristic classes to quantized differential forms to secondary objects. Cohomological theory can lead to a good mathematical theory for Feynman integrals. 2. Applications up: theory of diffieties. Applications down: propagation of singularities of PDE, classical limit. 3. n-ary mathematics (like n-ary Lie brackets) as a background to statistical Physics. But our mentality is a one particle mentality. 4. Computer support for this activity: a very special kind of symbolic computation.

MICHOR: He is fascinated by algebraic aspects of differential calculus and its deformations, and by multigraded Lie brackets which detect Lie algebras, their representations, their deformations, and their cohomologies. This will surely be important.

He was also was involved in the past twenty years with infinite dimensional differential geometry, manifolds of mappings and diffeomorphisms. This led to the theory of general fiber bundles with structure the diffeomorphism group, connections, holonomy, characteristic classes for it. This is tied with a revised calculus in infinite dimensions, developed by Frölicher and Kriegl, which also sheds new light on the theory of locally convex spaces and algebras.

BUDINICH: He has seen many fashions characterized by crowds producing useless papers mainly for career's reasons. ESI should encourage also young people who wish to deviate from fashions. Simple or pure spinor-geometry could be a good subject for study at ESI to deal with yet obscure corners of physics like global properties of fermions in conformal extensions of space time, unified or standard models, superconductivity.

Now followed an intensive discussion on the role of quantum groups in Mathematical Physics.

Wednesday evening, Heuriger. FADDEEV: In communist countries, Mathematics and Mathematical Physics was a sort of sheltered retreat for talented people to find independence. Thus the best intellects were drawn to it. This will change now, and emigration is going, but the ESI can still get some very good scientists. The quality/cost ratio for the ESI is the very best possible for any scientific enterprise which seems possible for Austria just now. But it is urgent to act quickly. Best quality will be assured.

Thursday morning, concrete proposal. SOME DISCUSSION: a theoretical physicist on the board (Souček, who is mathematician), lacks dynamical systems, condensed matter physics (Fröhlich), Hungary and Romania are lacking (Thirring).

ELECTION OF THE CHAIRMAN:. Unanimously (13) for Thirring (Reiter abstained).

Scientific Council. The members of the workshop constitute themselves as scientific committee of the institute. Also V. Drinfeld is elected by acclaim in order to give more weight to mathematics.

Size. Recommendation of 40 Scientists. Up to 6 permanent positions besides directors, in the long run.

Administration. 1 Administrative director. 3 secretaries, one for the director, one for visitors, one for typing. 1 accountant. 1 computer support. 2 librarians. This excludes housekeeping and personal for the housing.

Directorate or advisory committee. Faddeev, Fröhlich, Connes; Thirring, Michor, Narnhofer as advisory committee, Thirring as director.

Conference. Faddeev proposes to meet again with a scientific conference 'Interfaces between Mathematics and Physics', not more than 30 active participants. Date March 1 – 8, 1992, at the university of Vienna. All present agree to come, more expository talks, program starting from names rather than topics. Philosopher Alan Janik as introductory lecturer (Reiter).

Finale. TRAUTMAN: The idea of this institute is so good that it may be stolen and such an institute might be created elsewhere. It is essential to act quickly.

As name was adopted:

Erwin Schrödinger International Institute for Mathematical Physics (ESI)

Discussion after the end lead to the conviction that the ESI should be created immediately, its interim activities being the organization of workshops and conferences, until budget and location is found.

Erwin Schrödinger International Institute (Vertiefungsstudie)

Wir analysieren den Zweck, den Aufwand und den Nutzen eines Internationalen Erwin Schrödinger-Instituts für Mathematische Physik (abgekürzt ESI). Wir empfehlen ein Institut mit etwa 40 wissenschaftlichen Mitarbeitern, zur Hälfte aus Ost-, zur Hälfte aus Westeuropa, welche auf dem interdisziplinären Gebiet der mathematischen Physik forschen. Das Jahresbudget eines solchen Instituts würde sich auf etwa ATS 34,000.000 (ohne Gebäudekosten) belaufen. Ein solches Institut könnte ein Zeichen für die kulturelle Bedeutung Österreichs im mitteleuropäischen Raum setzen.

Inhalt.

1. Die wissenschaftliche Situation. Die mathematische Physik ist das Wissensgebiet, in dem sich Mathematik und Physik überlappen, wo wir versuchen, die mathematische Form der physikalischen Gesetze zu finden und ihre Konsequenzen abzuleiten. Die reine Mathematik ist bestrebt, Denkstrukturen zu erkennen, und ist so eine theoretisch in sich geschlossene Wissenschaft. Sie besteht scheinbar ohne Anwendung auf andere Gebiete, wurde aber tatsächlich immer durch Impulse, die aus der Physik kamen, befruchtet. Die Aufgabe der Physik ist es, die Natur mit der Sprache der Mathematik zu beschreiben. Je komplexer das zu begreifende Phänomen, desto feingeschliffeneres mathematisches Werkzeug ist dafür erforderlich. So kam es, daß in den letzten Jahrzehnten die Physiker sich immer mehr des Reichtums der von den Mathematikern gebotenen Methoden, seien sie analytisch, geometrisch oder numerisch, bewußt wurden und die mathematische Physik aufblühte. Hinzu kam, daß man in der Elementarteilchenphysik in einem Bereich angelangt ist, in dem Versuche ungeheuer aufwendig und kostspielig werden und neue experimentelle Erkenntnisse dementsprechend langsam einfließen. Dies gibt dem Theoretiker die Muße, das vorhandene Material geistig zu verarbeiten, und immer wieder erweist es sich als nötig, die vertraute Begriffswelt zu verlassen. Die dabei hervortretenden Denkstrukturen gaben ihrerseits wieder der Mathematik Anregungen, die etwa in den neuen Entwicklungen wie nicht kommutative Geometrie, topologische Feldtheorien, Quantengruppen etc. ihren Niederschlag fanden. Symptomatisch für diese Entwicklung ist etwa, daß von den vier bei dem letzten internationalen Mathematikerkongress verliehenen Fields-Medaillen, drei an die mathematische Physik gingen. Alles in allem ist dieser Grenzbereich von Mathematik und Physik zur Zeit in einer Aufbruchsstimmung. Die bisher erzielten Erfolge berechtigen zur Hoffnung, daß sich auch in den nächsten Jahren hier revolutionierende Erkenntnisse erschließen werden.

2. Die politische Situation. Die Jahre 1989 und 1990 brachten revolutionäre Veränderungen in Mittel- und Osteuropa. Die kommunistischen Regime der Satellitenländer der Sowjetunion wurden unter dem Druck ihrer Bevölkerung von freigewählten Regierungen abgelöst und selbst in der Sowjetunion entwickeln sich demokratische Strukturen. Die wirtschaftliche Genesung dieser Länder ist aber ein langsamer und schmerzlicher Prozeß, unter dem besonders die staatlichen wissenschaftlichen Institutionen leiden. Dementsprechend ergibt sich für diese Länder ein gewaltiger intellektueller Aderlaß, da die besten Leute in anderen Ländern bessere Arbeits- und Lebensbedingungen suchen. Der Hauptgewinner dieser Entwicklung sind wieder einmal die USA, da ihre wissenschaftlichen Institutionen über die nötige Flexibilität und Mittel verfügen. Zur Wahrung der kulturellen Potenz eines vereinten Europas wäre es bitter nötig, dieser Tendenz entgegenzuwirken. Insbesondere hat Mitteleuropa hier auf naturwissenschaftlichem Gebiet eine wertvolle Tradition zu bewahren. Es ist allgemein bekannt, wieviele geistige Strömungen der letzten Jahrhundertwende in Literatur, Musik, bildender Kunst, Philosophie, Medizin in der Donaumonarchie ihre Quelle besaßen und sogar noch unter den schwierigen Verhältnissen der ersten Republik deren geistige Potenz bewiesen. Weniger bekannt ist, daß auch wesentliche Ideen, von denen die Mathematik und die Physik dieses Jahrhunderts zehren, hier ihren Ausgangspunkt haben. Dazu sei an Funktionalanalysis (Banach, Hahn), Homotopietheorie (Cech, Hurewicz), Maßtheorie (Radon, Nikodym), mathematische Logik (Gödel), statistische Mechanik (Boltzmann), Quantenmechanik (Schrödinger) erinnert.

Daß an Österreich von außen her der Vorschlag eines internationalen Schrödinger Instituts in Wien herangetragen wurde, mag als Zeichen dafür gewertet werden, daß sich die hier wiederentstandene Schule für mathematische Physik ihres Erbes würdig erwiesen hat.

Ein weiterer Grund liegt wohl auch darin, daß die Institute für theoretische Physik und für Mathematik der Universität Wien immer schon den Kontakt mit dem Osten gepflegt haben. Wir verweisen auf das Triangelseminar, das seit mehr als zwanzig Jahren besteht und in dessen Rahmen sich Elementarteilchenphysiker aus Bratislava, Budapest, Wien und später auch Prag, Zagreb und Triest viermal im Jahr treffen. Brünn und Wien veranstalten seit sechs Jahren einmal monatlich ein mitteleuropäisches Seminar zur Differentialgeometrie, ein entsprechendes Seminar findet seit einem Jahr auch einmal monatlich gemeinsam mit Budapest statt. Einmal im Jahr organisiert das Institut für theoretische Physik das Boltzmann-Seminar über statistische Physik mit Teilnehmern aus Ungarn, Polen, Tschechoslowakei und der ehemaligen DDR. Aufgrund seiner gereiften demokratischen Staatsform, der stabilen Marktwirtschaft, der geographischen Lage und der kulturellen Tradition erwächst jetzt für Österreich nicht nur die Chance, sondern sogar die Verpflichtung, die gegenwärtige Situation zu nützen und wieder das geistige Zentrum von Mitteleuropa zu werden.

3. Institutionen für Grundlagenforschung. Von Platos Akademie in Athen über die von Leibniz ins Leben gerufenen Akademien bis zum heutigen Tage gab es immer Bestrebungen, Institutionen zu schaffen, die hervorragenden Gelehrten die ihnen angemessenen Arbeitsbedingungen bieten. In unserem Jahrhundert ging ein entscheidender Impuls von Abraham Flexner (USA) aus, welcher die reiche Bamberger Familie dazu bewog 1930 mit einer Stiftung in Princeton das Institute for Advanced Study (IAS) zu gründen. Seinen weltweit anerkannten Erfolg verdankt es teils dem Weitblick seiner Gründer, welcher auf höchste wissenschaftliche Qualität auf internationaler Ebene gerichtet war, teils auch der Gunst der Stunde. Vertrieb doch gerade damals Hitlers politischer Wahnsinn die besten Köpfe aus Europa und man konnte sich aus deren Schar Gelehrte wie Einstein, Gödel, von Neumann und Weyl aussuchen. Diesem Unterfangen folgten Nachahmungen, zunächst langsam, dann lawinenartig.

1940 gründete de Valera in Dublin das kleinere 'Institute of Advanced Studies', welches Schrödinger beherbergen sollte, und 1958 folgte das 'Institute des Hautes Etudes Scientifiques' in Bures-sur-Yvette bei Paris. Das Prestige dieser Institute ließ allenthalben den Wunsch nach Ähnlichem aufkommen und zurzeit kann man folgende Liste allein für die mehr mathematisch orientierten Institutionen anführen:

- Mittag Leffler Institute in Stockholm
- Mathematical Science Research Institute in Berkeley
- Max-Planck-Institut für Mathematik in Bonn
- Forschungsinstitut für Mathematik, ETH Zürich
- SISSA in Triest, ICTP in Triest
- Mathematics Institute at the University or Warwick/UK
- Isaac Newton Institute of Mathematical Sciences in Cambridge
- Euler International Institute in St. Petersburg (Leningrad)
- The Banach Center, Warsaw
- Le Centre Physique Theorique, Marseille
- Das Forschungsinstitut Oberwolfach, Deutschland
- The Institute of Scientific Interactions, Torino
- The TATA Institute for Fundamental Research in Bombay
- Das Zentrum für Interdisziplinäre Forschung, Bielefeld

Die Zielsetzungen dieser Institutionen variieren stark, für ihre Existenzberechtigung läßt sich allgemein folgendes anführen: Das Ideal der Einheit von Forschung und Lehre in allen Ehren, aber für einen Wissenschafter besteht doch das Bedürfnis, sich von Zeit zu Zeit ganz der Forschung widmen zu können. Insbesondere zu Beginn der Karriere ist es wichtig, nicht gleich in die Lehre eingegliedert zu werden, sondern die produktivsten Jahre nach dem Doktorat nur für Forschung und Studium zu nützen. Ein idealer Arbeitsplatz ist dafür ein Forschungsinstitut, in dem erstrangige Gelehrte arbeiten, die als Leitfiguren Anregungen liefern. Wichtig ist dabei Mobilität, sodaß immer neue Gäste kommen, um ihre Ideen reifen zu lassen und auszuarbeiten. Natürlich soll dies nicht in Isolation geschehen, sondern man muß durch Seminare und Diskussionen stets neue Impulse setzen und empfangen. Daher müssen die Institute so geführt sein, daß sie ein entsprechendes Arbeitsklima bieten. Die eben angeführten Gesichtspunkte zeigen, daß ein solches Institut nur reüssieren kann, wenn folgende Bedingungen erfüllt sind:

1. Ein Institut braucht eine gewisse Minimalgröße, bei zu kleinen Instituten wird es zu unwahrscheinlich, den geeigneten Gesprächspartner zu finden. Erfahrungsgemäß liegt die kritische Größe bei 30-40 Wissenschaftern. Darüber hinaus wächst die Effizienz nicht weiter, weil man nicht alle Möglichkeiten ausnützen kann.
2. Um die besten Gelehrten anzuziehen, müssen auch Gebäude und Lage des Institutes attraktiv sein. Angesichts der vielen Möglichkeiten werden sich die Spitzenleute natürlich das Angenehmste aussuchen.
3. Da viele Leute nur auf kürzere Zeit kommen, muß die Administration dafür eingerichtet sein, ihnen sofort die Notwendigkeiten für das tägliche Leben bereitzustellen, damit sie ihre Zeit effizient für die wissenschaftliche Tätigkeit nützen können. So haben viele Institute, wie das in Princeton oder in Bures-sur-Yvette, ein eigenes 'Housing Project' (Gästehäuser), so daß Besucher nicht auf Wohnungssuche gehen müssen. (Direktor Goldberger vom IAS Princeton erklärte stolz, seine Gäste müssen nur die eigene Zahnbürste mitbringen.)
4. Das Institut muß eine klar definierte Zielsetzung haben und deren Aktualität muß immer überprüfbar sein. Anderenfalls kann es, wie Beispiele zeigen, durch die stets zu erwartende Kritik in eine Identitätskrise gestürzt werden.

Da die theoretischen Forschungsinstitute keine gigantischen Geräte und daher weniger Hilfspersonal erfordern, sind ihre Kosten geringer als für experimentelle oder industrielle Anlagen. Zum Vergleich mit den späteren Budgetansätzen für das ESI geben wir hier die Daten von drei typischen Institutionen in ganz verschiedenen Ländern. Es zeigt sich, daß die Kosten pro Mann/Jahr nicht wesentlich variieren:

1. Institute for Advanced Study in Princeton:

   200 Wissenschafter arbeiten in den Gebieten Geschichte, Mathematik, Physik, Soziologie. In jedem Gebiet sind im Schnitt sechs Professoren permanent beschäftigt, der Rest sind Gäste. Das Budget für 1989 betrug US $ 14,362.376 oder ca. aTS 172,000.000. Auf einem großen parkartigen Gelände sind Bürogelände, Mensa und Gästewohnungen untergebracht.

2. L'Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette nahe Paris:

   Das Institut liegt auf dem Gelände eines ehemaligen Schlosses. Im Schnitt arbeiten hier 35 Wissenschafter (Mathematik und Physik), davon 6 permanente Professoren. Die Administration besteht aus 8 Angestellten. Die Kosten 1990 betrugen für permanente Professoren und Angestellte 10,5 MF, für Gäste 3,5 MF, für den Betrieb 5,6 MF, mit Gebäudekosten insgesamt 21,9 MF also aTS 45,000.000.

   Dabei ist zu berücksichtigen, daß die eigene Bibliothek als zu klein eingeschätzt wird und die Bibliothek der Universität Orsay (20 Gehminuten) mitverwendet wird.

3. Nordita in Kopenhagen:

   Hier arbeiten sechs permanente Professoren, vier langfristige Mitarbeiter (für sechs Jahre), im Schnitt 25 Gäste unter der Betreuung von acht Administratoren. Das Institut erhält das Forschungsgebäude. Bibliothek, Mensa etc. vom Niels Bohr- Institut können benutzt werden. Wohnungen werden nicht zur Verfügung gestellt, nur bei der Suche wird geholfen. Konferenzen werden unterstützt und mitorganisiert. Das Budget 1989 betrug dafür DEM 14,605.000, also ungefähr aTS 26,500.000.

Das Erwin Schrödinger-Institut. Der bekannte russische Mathematiker Vinogradov regte an, in Wien ein Institut für mathematische Physik zu gründen, welches als Treffpunkt der in Ost- und Westeuropa auf diesem Gebiet arbeitenden Forscher dienen sollte. Es soll nach Erwin Schrödinger benannt werden, da das überragende Werk dieses großen österreichischen Denkers weite Teile der Physik und Mathematik geprägt hat. Sein Vorschlag wurde führenden Gelehrten unterbreitet und fand ein sehr positives Echo (siehe Anhang). Das veranlaßte das Bundesministerium für Wissenschaft und Forschung, etwa ein Dutzend bedeutender Persönlichkeiten aus Ost und West zu einem zweitägigen Workshop einzuladen, um diesen Vorschlag eingehender zu diskutieren. (Biographisches dieser Wissenschafter im Anhang.)

Die Reaktion war sehr erfreulich. Alle hatten ihre Zeit nicht nur zur Verfügung gestellt und sind gekommen, um an den Planungen teilzunehmen, sondern haben sich auch bereit erklärt, in einem 'Scientific Advisory Board' für dieses Institut zu dienen. Dies ist ein sehr wichtiger Schritt für ESI, denn nur durch ein hochqualifiziertes und international ausgewogenes Gremium kann höchste wissenschaftliche Qualität garantiert werden. Bei diesem Workshop (Protokoll liegt im Anhang bei) haben sich folgende Zielsetzungen ergeben:

1. Durch den Fall des Eisernen Vorhanges ist endlich ein freier Gedankenaustausch zwischen Ost und West möglich, und ESI soll auf dem Gebiet der mathematischen Physik dafür ein Heim bieten. Es kann dabei den Gelehrten der früheren kommunistischen Länder helfen, die schwierigen kommenden Jahre zu bewältigen. Für die totalitären Regime waren die Akademieinstitute Prestigeobjekte, die entsprechend gefördert wurden, was teilweise politischen Günstlingen zu Gute kam, teilweise auch sehr gute wissenschaftliche Schulen hervorrief.

   In einem marktwirtschaftlichen System wird sich ein solcher Aufwand nicht halten und drastische Sparmaßnahmen werden die Arbeit erschweren. Die Bibliotheksausstattungen zum Beispiel werden immer dürftiger, was für einen modernen Forschungsbetrieb tödlich ist. Als Folge werden die besten Leute emigrieren, so ist etwa die glänzende rumänische Mathematikerschule fast vollständig in den USA versammelt. Könnte man diesen Leuten temporär günstige Arbeitsbedingungen am ESI bieten, ließe sich vielleicht manches hinüberretten. Natürlich sollten aber gemäß seines Zwecks etwa die Hälfte der Mitarbeiter im ESI aus dem Westen stammen.

2. Als interdisziplinäres Gebiet bietet sich die mathematische Physik als Forschungsschwerpunkt an. Man kann sie grob vielleicht als den Teil der theoretischen Physik charakterisieren, der mit legalen mathematischen Methoden arbeitet und den Teil der Mathematik, dessen Wert sich an konkreten physikalischen Problemstellungen erweisen läßt. Eine genauere Festlegung wäre nicht angebracht, und es obliegt dem Weitblick der wissenschaftlichen Leitung von ESI, dann jeweils auf den richtigen Weg zu steuern.

3. Seinem Zweck entsprechend sollte ESI hauptsächlich kurz- oder langfristigeren Besuchern dienen. Doch der Glanz eines solchen Institutes lebt von großen Namen, so daß an eine kleine Zahl (etwa sechs aus 40) von permanenten Stellen gedacht ist. Selbstverständlich sollten diese Stellen nur besetzt werden, wenn es gelingt, eine hervorragende wissenschaftliche Persönlichkeit für ESI zu gewinnen.

Durch diese Zielsetzungen würde sich ESI klar von bestehenden Instituten unterscheiden und wäre nicht nur eine Kopie. Natürlich gibt es Überlappungen mit anderen Institutionen und der folgende Vergleich wird auch zeigen, was man aufbieten muß, um hier konkurrenzfähig zu sein.

1. Institute for Advanced Study, Princeton:

   Die etwa 200 Wissenschafter in den schon erwähnten Wissensgebieten wohnen auf einem Campus. Trotzdem gilt der Kontakt zwischen den Wissenschaftern als nicht optimal. Aufenthalte werden oft genutzt, um Bücher zu schreiben.

2. Mathematical Science Research Institute in Berkeley:

   Hier werden etwa dreimonatige Workshops veranstaltet. Das Schwergewicht liegt auf Seminaren.

3. Max Planck Institut für Mathematik in Bonn:

   Es ist auf Mathematik ausgerichtet und pflegt keinen Kontakt zur Physik.

4. Mittag-Leffler-Institut in Stockholm:

   Das Institut ist in der ehemaligen Privatvilla des Gelehrten Mittag-Leffler untergebracht. Bis auf einen Direktor arbeiten hier nur Gäste an halbjährigen Forschungsprogrammen aus Gebieten der Mathematik.

5. Mathematics Institute of the University of Warwick, UK:

   Es konzentriert sich auf Mathematik und dient vor allem als Gastinstitut für Professoren mit Freisemester.

6. Banach Center Warschau:

   Ähnlich wie in Berkeley werden Workshops organisiert, die über ein Semester dauern. Einer der maßgeblichen Leute, Professor Trautman, ist im Komitee von ESI.

7. Forschungsinstitut Oberwolfach, Deutschland:

   Hier finden hauptsächlich Konferenzen von einer Woche Dauer statt. Das Institut ist für Jahre ausgebucht. Es ist berühmt für seine ausgezeichnete mathematische Bibliothek.

8. Isaac Newton Institute of Mathematical Sciences in Cambridge, UK:

   Es befindet sich in Planung. Das Schwergewicht soll auf angewandter Mathematik liegen. Geplant sind Workshops und sechsmonatige Forschungsprogramme. Der Kontakt mit dem Osten wird nicht betont.

9. Euler Institute in St. Petersburg (Leningrad):

   Es ist in einem von der Stadt gestifteten ehemaligen Herrenhaus untergebracht, allerdings noch nicht voll eingerichtet. Es will dreimonatige Workshops organisieren. Dabei soll man sich zu Beginn auf Forschung und wenige Seminarvorträge konzentrieren und das Workshop mit einer Konferenz abschließen. Der Leiter des Instituts, L. Faddeev, ist auch Mitglied des Komitees von ESI.

10. ICTP in Triest:

    Das Gebäude des Instituts befindet sich direkt neben dem Park von Miramare. Es organisiert Konferenzen und Schulen, ein Schwergewicht liegt auf der Betreuung von Gästen aus der dritten Welt. P.Budinich, Initiator und langjähriger Vizedirektor von ICTP, ist Mitglied der Komitees von ESI.

11. Nordita, Kopenhagen:

    Hier wird nicht Mathematik, sondern Physik mit dem Schwergewicht auf Phänomenologie betrieben. Es wendet sich vor allem an die nordischen Länder.

12. IHES, Bures-sur-Yvette:

    Hier wird Mathematik und Physik betrieben, allerdings ohne die Gemeinsamkeit zu betonen und ohne besonders den Ostkontakt zu pflegen. Ansonsten ähnelt es am ehesten dem geplanten Institut in bezug auf Größe, Seminarbetrieb etc. A.Connes, der dort arbeitet, und J. Fröhlich, der im Advisory Board von IHES ist, sind Mitglieder des Komitees von ESI.

Organisationsform und Budget. Die österreichischen Hochschulgesetze sind nicht für eine internationale Zusammenarbeit grösseren Stils ausgelegt, so daß sich das ESI an internationalen wissenschaftlichen Institutionen in Österreich orientieren muß.

Wie bei IIASA bei Wien wäre ein Verein mit denselben durch Gesetze verankerten Rechten eine wesentliche Vorbedingung für einen effizienten und reibungslosen Betrieb. Die folgenden Budgetzahlen sollen nur die Größenordnung der wesentlichen Ausgaben fixieren, eine Ausarbeitung von Details wäre verfrüht. Ein großer Posten fehlt allerdings, nämlich der Betrieb des Gebäudes. Da diese Kosten zu sehr mit den Möglichkeiten variieren, wäre jede Zahl willkürlich.

Entsprechend der Zielsetzung des Instituts muß der Direktor über genügende Flexibilität in der Budgetgebarung verfügen. So muß er in vernünftigem Rahmen (etwa 30%) berechtigt sein, Mittel von einem Posten zu einem anderen oder von einem Jahr auf das nächste zu übertragen. Nur so kann er plötzlichen Veränderungen Rechnung tragen und Geldverschwendung vermeiden.

Jahresbudget (ohne Gebäude).

30 Professoren (6 permanent, 24 Gäste) à aTS 750.000 (im Schnitt)	22,500.000
10 Gäste (von auswärts bezahlt)	
8 administratives Personal à 500.000 (im Schnitt)	4,000.000
Bibliothek	5,000.000
Konferenzen und Workshops, Büromaterial, Publikationen	2,000.000
Reisekosten, Repräsentation	500.000
Summe	34,000.000

Bei den Gehaltskosten ergeben sich vermutlich starke Reduktionen, wenn man Pensionsversicherung oder Steuern einsparen kann, wie das in einem Verein, der sich am Beispiel der IIASA orientiert, der Fall wäre. Diese Schätzung zeigt, daß man um die anderenorts erprobten Zahlen nicht herumkommt. Es war nicht unser Ziel, andere Institute finanziell zu überbieten, aber wir hoffen, daß wir durch wissenschaftliches Klima und kulturelle Atmosphäre konkurrenzfähig werden.

Die Bibliothek. Die Bibliothekskosten orientieren sich an Vergleichen mit ICTP Triest und Universität Wien. Dabei haben wir eine Bibliothek ins Auge gefaßt, die das Institut ziemlich unabhängig von der Universitätsbibliothek machen sollte. Nicht berücksichtigt wurde das Startkapital für die Bibliothek. Hier muß es auf alle Fälle eine Übergangslösung geben (vgl. die Erfahrungen von Prof. Budinich in Triest), während der die Universitätsbibliothek zur Verfügung steht. Eine gute Bibliothek wird gerade für die Wissenschafter aus dem Osten (die in ihrer Heimat Sparmaßnahmen fürchten) eine Attraktion des ESI bieten. In Zusammenarbeit mit der Zentralbibliothek für Physik der Universität und deren Mathematikbibliothek könnte man sie zu einer Zentralbibliothek für Mitteleuropa auf dem Gebiet ausbauen.

Der Raumbedarf. Da keine besonderen Installationen notwendig sind, ließe sich fast jedes Gebäude für das Institut verwenden, es ist nur eine Frage, wie effizient der Raum genutzt werden kann. Wichtiger ist eine ruhige Lage, da Lärmbelästigung für konzentriertes Denken hinderlich ist. So sind viele der analogen Institute (Princeton, Bures-sur-Yvette, Bielefeld) an einem Wald oder Park gebaut, denn nach angespannter intellektueller Arbeit, ist es heilsam, den Kopf bei einem Spaziergang auszulüften. Andererseits wäre es für die Universität sehr günstig, wenn das ESI verkehrstechnisch gut erreichbar ist, und es bleibt abzuwägen, was der günstigste Kompromiß sein wird. Für das Institut selbst kann man folgenden Raumbedarf abschätzen.

35 Arbeitszimmer + 6 Arbeitszimmer für die Administration	600 m^2
2 Seminarräume (für 60 bzw. 30 Zuhörer)	200 m^2
1 Teeraum (könnte ein Seminarraum sein)	50 m^2
1 Raum für technische Geräte	50 m^2
Bibliothek	700 m^2
Kantine (falls nicht Möglichkeit kleiner Restaurants wie in Universitätsnähe)	$150m^2$
Insgesamt	1750 m^2

Ein Gästehaus erscheint ebenfalls sehr wichtig. Nicht nur erfreuen sich Institute mit solcher Möglichkeit (Princeton, Bures-sur-Yvette, Bielefeld) größerer Beliebtheit, sondern auch finanziell wäre dies zweifelsohne rentabel. Der Bedarf wäre etwa: 20 Einzelzimmer (am günstigsten in kleine Apartments zusammengefaßt), 5 Doppelzimmer, 5 kleinere Apartments. Rechnet man diesen Raumbedarf mit (20 x 15 m^2 + 5x 20 m^2 + 5 x 50 m^2 = 650 m^2), was bei Baukosten von aTS 25.000/m^2 eine Investition von S 16,250.000 bedeutet. Rechnet man die Hotelkosten nach, so ist zu bedenken, daß man internationalen Spitzenleuten nicht die schlechtesten Hotels zumuten kann. Die Preise der besseren Hotels in Wien liegen bei S 1.000 – 4000 und auch wenn man sich am unteren Ende ansiedelt, kommt man auf aTS 300.000/Mann/Jahr. Nachdem von den 40 Mitarbeitern etwa 30 im Hotel leben müssen, würde das Jahresbudget mit aTS 9,000.000 durch Hotelkosten belastet und das Gästehaus hätte sich nach zwei Jahren amortisiert, auch wenn man den zusätzlichen Personalbedarf berücksichtigt. Zur besseren Auslastung wäre es günstig, das Gästehaus mit der Universität oder (und) der IIASA zu betreiben, wenn ESI in Wien oder Laxenburg sein wird. Beide Institutionen leiden darunter, kein Gästehaus zu besitzen, nach Gesprächen mit Dir. Dr. Peter E. de Jànosi wäre die IIASA an einem solchen Projekt sehr interessiert.

Die Finanzierung von ESI. Obwohl das Institut international verankert sein soll (internationales wissenschaftliches Komitee, europaweites Forschungsteam), so muß man damit rechnen, daß die Hauptlast der Finanzierung bei Österreich liegt. So wird auch das IHES in Bures-sur Yvette zu 75% von Frankreich finanziert und das ICTP in Triest zu noch größerem Teil von Italien. Gäste aus den ehemaligen Ostblockländern werden kaum finanzielle Unterstützung aus der Heimat mitbringen können (und falls sie ihr Gehalt mitbrächten, würde es hier nicht die Lebenskosten decken).

Doch da es sich um eine gesamteuropäisches Projekt handeln soll, muß man sich auch um außerösterreichische Geldquellen kümmern. Leider überblicken wir die zahllosen wissenschaftlichen Programme und Agenturen zuwenig, um zu wissen, welche Quelle am ergiebigsten wäre. Etwa könnte man hoffen, über die Commission of the European Communities einige Stellen zu finanzieren. So finanziert der Scienceplan/Twinning Stellen, wenn dadurch Kontakte zwischen Forschungsinstituten verschiedener Länder ermöglicht werden. Hier bietet sich vielleicht Zusammenarbeit mit IHES an.

Jedenfalls haben die italienischen und spanischen Vertreter im Scientific Committee von ESI in Aussicht gestellt, Forscher aus ihren Ländern am ESI zu finanzieren. Ferner gibt es Stiftungen (Humboldt Stiftung, Heisenberg Stipendium), welche analog unserem Schrödinger Stipendium ihren Stipendiaten die Wahl des Arbeitsplatzes freistellen, und wir könnten solche Leute sicher anziehen, wenn wir etwas Attraktives zu bieten hätten. Schließlich könnte von privaten Sponsoren (etwa großen Versicherungen wie Generali) vielleicht eine nach ihnen benannte Gastprofessur gestiftet werden.

Der Nutzen für Österreich. ESI wäre für unsere Wissenschaft ungeheuer wichtig, weil die österreichischen Universitäten an manchen strukturellen Schwächen leiden, die es trotz vieler Bemühungen verhindert haben, daß Österreich auf dem naturwissenschaftlichen Sektor völlig in den internationalen Spitzenbetrieb integriert ist. Einerseits sind unsere Gastprofessuren zu schlecht dotiert, so daß sie für die führenden Geister keinerlei Anreiz bieten. Daher kommen dann Leute, die auch nicht mehr können als die ansässigen, und das Geld ist eigentlich verschwendet. Ferner haben wir keine Postdoc Stellen und können junge Forscher in ihrer produktivsten Phase nicht nutzen. Durch das ESI könnte Österreich an dem geplanten 'European pool of postdoc positions' teilnehmen und einerseits hoffnungsvolle ausländische Kräfte nach Wien holen und andererseits unseren Studenten nach dem Doktorat einen guten Start für eine internationale Karriere bieten.

In den letzten Jahren hat sich eine sehr eifrige Gruppe von Doktoranden und Diplomanden in mathematischer Physik gebildet, und durch ESI würden sie die nötigen internationalen Kontakte und Erfahrungen bekommen, um ihren Arbeiten Weltgeltung zu verschaffen. Schließlich wäre es auch für die arrivierteren Herren (oder Damen) ein Ansporn sich mit der Weltelite messen zu müssen. Natürlich wächst der Nutzen für Österreich mit den guten Kontakten zu den Universitäten, und dieser Kontakt ist umso besser, je näher Institut und Universitäten beisammen liegen.

Pläne für die nächste Zukunft. Wer schnell hilft, hilft doppelt und es ist keine Zeit zu verlieren, wenn ESI seinen Zweck erfüllen soll. Auch muß man anderwärtigen ähnlichen Bestrebungen zuvorkommen, denn zurzeit wäre ESI in seiner Zielsetzung einzigartig in Europa, aber jemand anderer könnte uns den Wind aus den Segeln nehmen. Solange wir noch kein grünes Licht bekommen haben, wollen wir wenigstens mit einigen Workshops beginnen, die sich mit den geringsten Mitteln durchführen lassen.

Wenn man ein größeres und zwei kleinere Workshops ins Auge faßt, so ergeben sich nach unseren Erfahrungen die Kosten von 150.000 aTS + 2x 75.000 aTS = 300.000 pro Jahr. Diese Workshops sollten gleich den Zielsetzungen von ESI entsprechen und Physiker und Mathematiker aus Ost und West zusammenbringen. Für das Jahr 1992 ist folgendes Programm vorgesehen:

1. Der große Workshop soll 'Interfaces between Physics and Mathematics' heißen und ein Panorama über die verschiedenen für ESI maßgeblichen Entwicklungen liefern. Im Komitee von ESI vertretene Gelehrte haben sich dankenswerter Weise als Sprecher zur Verfügung gestellt, und der Herr Bundesminister hat seine Unterstützung zugesagt. Das Programm für dieses Workshop liegt bei.
2. Der russische Mathematiker Kirillov, die Autorität auf dem Gebiet der Darstellungstheorie, ist bereit, ein Workshop darüber zu organisieren. Die wissenschaftliche Organisation würden neben ihm sein Mitarbeiter Rudakov und Professor Michor von der Universität Wien übernehmen.
3. Drei Vertreter der berühmten rumänischen Schule über Operatoralgebren (S. Popa, D. Voiculescu, A. Ocneanu) verbringen das Jahr 1992 in Westeuropa. Dieses Forschungsgebiet ist für die Wiener Gruppe wichtig, und außerdem wären dies Kandidaten von Ostflüchtlingen, die ESI wieder nach Europa zurückbringen könnte. In Zusammenarbeit mit Prof. Narnhofer und Prof. Thirring von der Universität Wien ist daher ein Workshop über Operatoralgebren geplant.

Durch den Enthusiasmus für ESI sind noch weitere Anregungen an uns herangetragen worden, die wir aber erst 1993 ins Auge fassen können:

1. Der Initiator von ESI, Prof. Vinogradov, will mit starker internationaler Besetzung (Grabowski (Polen), Krashilchil (Rußland), Lecomte (Belgien), Roger (Frankreich), Michor (Wien)) ein Workshop über sein Spezialgebiet 'n-ary Lie- and associative Algebras' organisieren.
2. Die Boltzmannsche Tradition wahrend hat die Wiener Gruppe für mathematische Physik jährlich einmal ein Seminar über die Grundlagen der statistischen Mechanik organisiert. Dies war schon vor der Öffnung des Eisernen Vorhanges ein Treffpunkt von mathematischen Physikern aus Ost und West. Wegen der vielen anderen Ereignisse kann es 1992 nicht stattfinden, doch sollte diese Tradition 1993 weiter gepflegt werden.
3. Ein weiterer Vorschlag, der an uns von Kirillov herangetragen wurde, ist ein Workshop über Quantengruppen. Die wissenschaftliche Organisation läge in den Händen von Rudakov (Rußland), Woronowicz (Polen), Wess (Deutschland), Michor und Grosse (Wien).

Schlußbemerkungen. Da das Institut hauptsächlich kurzfristige Mitarbeiter hat, ist im Budget eine gewisse Flexibilität gegeben. Außerdem könnte es durch manche Faktoren (z.B. Steuerfreiheit für die Mitarbeiter, weitere Sponsoren) entlastet werden. Entscheidend ist es, eine Atmosphäre zu schaffen, welche die besten Gelehrten anzieht. Dieses Flair wird von den permanenten Mitgliedern geschaffen, von einer hilfreichen Administration und von Lage und Ausstattung des Gebäudes.

Hat man diesbezüglich nichts zu bieten, könnte das Institut die ihm gestellte Aufgabe nicht erfüllen, sondern bliebe nur eine zweitrangige Kopie vorhandener Institutionen, für die wir nicht mit gutem Gewissen eintreten könnten. Angesichts der großen kulturellen Tradition unseres Landes, von der wir noch immer zehren und die es mit allen Kräften und Mitteln zu verteidigen und fortzusetzen gilt, wäre jede andere als eine attraktive und großzügige Lösung eine unwiederbringlich versäumte Gelegenheit.

Peter W. Michor, Heide Narnhofer, Walter Thirring
Universität Wien
Fall 1991

Appendix B: The ESI Preprint series

The preprint series and its publication record

The ESI preprint series was started in 1993 and put on an FTP-server in 1994. This server has since become one of the major international archives of mathematical documents in the world with currently around 15.000 downloads each year.

The bibliographical information on the ESI-preprints up to the end of 1999 has been brought up to date with the help of Zentralblatt Math and Mathematical Reviews. For this information it is apparent that the vast majority of these preprints are published in major international research journals.

The cut-off point of December 31, 1999 is motivated by the slow publishing cycle in mathematics and the additional delay until the necessary data enter into MathSciNet and the Zentralblatt. Hence, a total of 819 preprints entered the evalution. Among these 819 preprints, 669, that is about 82%, were published in refereed journals or as part of collections. The vast majority of 586 (i.e. 85% of the published preprints) have appeared in refereed journals (including supplementa) while 83 of the published preprints (about 15%) appeared as parts of collections. Concerning the quality of the preprints, we have based the evaluation on the citation index of the ISI journal citation reports (with all the necessary reservations one has to have about this ranking). For each of the relevant categories 'Mathematics', 'Mathematics, applied', 'Physics, condensed matter', 'Physics, mathematical', 'Physics, multidisciplinary', and 'Physics, particles and fields', we have looked at the top 10% of the journals in that category. Remarkably, 108 of the 819 ESI preprints produced in the years between 1993 and 1999 have appeared in such top 10% journals. This means that about 13% of all the ESI preprints made it into journals of highest quality. The table below collects information on the publication data of all the preprints that we know of (i.e. not only those produced before 2000) at the time of writing of this page (August 2002). The first list contains the name of the journal (according to the journal database of the AMS), then the number of ESI preprints which have appeared in that journal. Finally, journals that are among the top 10% in at least one of the categories listed above in the ISI journal citation index are indicated by a *, followed by the name of the particular category in brackets.

Together with the second list below of journals in which a single ESI preprint has appeared this shows that in less than 10 years of the existence of the ESI, 144 ESI preprints have been published in top 10% journals.

Acta Appl. Math.: 2.
Acta Math.: 2. *(Mathematics)
Acta Math. Univ. Comenian.: 7.
Acta Phys. Polon. B: 3.
Adv. Math.: 4. *(Mathematics)
Adv. Theor. Math. Phys.: 2.
Ann. Global Anal. Geom.: 9.
Ann. Henri Poincaré: 4.
Ann. Inst. H. Poincaré Phys. Théor.: 5.
Ann. Inst. H. Poincaré Probab. Statist.: 2.
Ann. of Math.: 5. *(Mathematics)
Ann. Physics: 4.
Ann. Sci. École Norm. Sup.: 2. *(Mathematics)
Arch. Math. (Brno): 2.
Asian J. Math.: 3.
Asymptot. Anal.: 3.
Classical Quantum Gravity: 25.
Colloq. Math.: 2.
Comm. Math. Phys.: 54. *(Physics, mathematical)
Comm. Partial Differential Equations: 4.
C. R. Acad. Sci. Paris Sér. I Math.: 8.
Differential Geom. Appl.: 10.
Duke Math. J.: 9. *(Mathematics)
Ergodic Theory Dynam. Systems: 15.
Eur. Phys. J. C: 2.
Fortschr. Phys.: 2.
Fund. Math.: 3.
Geom. Dedicata: 6.
Geom. Funct. Anal.: 6. *(Mathematics)
Hadronic J.: 7.
Indiana Univ. Math. J.: 4.
Integral Equations Operator Theory: 2.
Internat. J. Theoret. Phys.: 4.
Internat. Math. Res. Notices: 2.
Int. J. Math.: 3.
Int. J. Mod. Phys. A: 3.
Invent. Math.: 6. *(Mathematics)
Israel J. Math.: 5.
J. Algebra: 5.
J. Anal. Math.: 2.

J. Approx. Theory: 2.
J. Funct. Anal.: 8.
J. Geom. Anal.: 2.
J. Geom. Phys.: 26.
J. High Energy Phys.: 10. *(Physics, particles and fields)
J. Lie Theory: 5.
J. London Math. Soc.: 3.
J. Math. Phys.: 57.
J. Math. Pures Appl.: 3.
J. Math. Sci. (New York): 2.
J. Nonlinear Math. Phys.: 4.
J. Operator Theory: 2.
J. Phys. A: 14.
J. Pure Appl. Algebra: 3.
J. Statist. Phys.: 7.
K-Theory: 3.
Lett. Math. Phys.: 27.
Markov Process. Related Fields: 2.
Math. Ann.: 3.
Math. Notes: 3.
Math. Phys. Electron. J.: 2.
Math. Proc. Cambridge Philos. Soc.: 3.
Math. Z.: 3.
Mem. Amer. Math. Soc.: 4. *(Mathematics)
Modern Phys. Lett. A: 4.
Monatsh. Math.: 7.
Moscow Math. J.: 2.
Nonlinearity: 2. *(Mathematics, applied)
Nuclear Phys. B: 18.
Nuclear Phys. B Proc. Suppl.: 2.
Osaka J. Math.: 2.
Pacific J. Math.: 2.
Phys. A: 2.
Phys. Lett. A: 2.
Phys. Lett. B: 21. *(Physics, multidisciplinary)
Phys. Rev. D: 27.
Phys. Rev. Lett.: 8. *(Physics, multidisciplinary)
Probab. Theory Relat. Fields: 2.
Proc. Amer. Math. Soc.: 8.
Proc. Roy. Soc. Edinburgh Sect. A: 2.
Proc. Roy. Soc. London Ser. A: 2.
Proc. Steklov Inst. Math.: 3.
Rend. Circ. Mat. Palermo Suppl.: 4.
Rend. Sem. Mat. Univ. Pol. Torino: 2.
Rep. Math. Phys.: 6.
Rev. Math. Phys.: 17.
Selecta Math.: 3.
St. Petersburg Math. J.: 3.
Theor. Math. Phys.: 3.
Trans. Amer. Math. Soc.: 10.
Transform. Groups: 4.
Transport Theory Statist. Phys.: 4.
Ukrain. Fiz. Zh.: 3.
Z. Angew. Math. Phys.: 3.

The following is a list of journals in which a *single* ESI preprint has appeared. The top 10% journals (as described above) are again indicated by a * with the category in brackets.

Aequationes Math.
Amer. J. Math. *(Mathematics)
Ann. Inst. Fourier (Grenoble)
Ann. Mat. Pura Appl.
Ann. Polon. Math.
Ann. Probab.
An. Univ. Timis., Ser. Mat.-Inform.
Arch. Ration. Mech. Anal.
Ark. Mat
Banach Center Publ.
Bull. London Math. Soc.
Bull. Polish Acad. Sci. Math.
Cahier Topol. Geom. Diff. Categor.
Calc. Var. Partial Differential Equations
Canad. J. Math.
Comm. Algebra
Comment. Math. Univ. Carolin.
Comm. Pure Appl. Math. *(Mathematics; Mathematics, applied)
Comput. Geom.
Discrete Comput. Geom.
Discrete Math.
Dokl. Akad. Nauk
Dopov. Nats. Akad. Nauk Ukr. Mat. Prirodozn. Tekh. Nauki
Electron. J. Differential Equations
Electron. Res. Announc. Amer. Math. Soc.
European J. Appl. Math.
Expo. Math.
Forum Math.
Found. Phys.
Funktsional. Anal. i Prilozhen.
Gen. Math.
Helv. Phys. Acta
Hokkaido Math. J.
Indag. Mathem.
Infin. Dimens. Anal. Quantum Probab. Relat. Top.
Interfaces Free Bound.
Internat. J. Modern Phys. B
Internat. J. Modern Phys. D
Int. J. Math. Math. Sci.
Int. J. Mod. Phys. D
Int. Math. Res. Notices
Izv. Math.
Izv. Nats. Akad. Nauk Armenii Mat.
J. Amer. Math. Soc. *(Mathematics)
J. Appl. Math. Stochastic Anal.
J. Differential Equations *(Mathematics)
J. Differential Geom.
J. Dynam. Control Systems
J. Geom.
J. Group Theory Phys.
J. Math. Anal. Appl.
J. Math. Soc. Japan
J. Reine Angew. Math.
J. Symb. Comput.
J. Symbolic Logic
J. Theoretical Probab.
Linear Algebra Appl.
Lobachevskii J. Math.
Manuscr. Math.
Mat. Contemp.
Matem. Studii
Mat. Fiz. Anal. Geom.
Math. Models Methods Appl. Sci.
Math. Nachr.
Math. Res. Lett.
Math. Scand.
Modern Phys. Lett. B
Nonlinear Anal.
Nova J. Theor. Phys.
Particles & Nuclei
Phys. D *(Mathematics, applied)
Phys. Rep. *(Physics, multidisciplinary)
Phys. Rev. A
Phys. Rev. B *(Physics, condensed matter)
Phys. Rev. E *(Physics, mathematical)
Proc. London Math. Soc. *(Mathematics)
Progr. Theoret. Phys. Suppl.
Publ. Math. Debrecen
Random Structures Algorithms
Rend. Mat. Appl.
Rev. Mat. Iberoam.
Rev. Roumaine Math. Pures Appl.
Sb. Math.
SIAM J. Appl. Math. *(Mathematics, applied)
SIAM J. Math. Anal.
SIAM J. Sci. Comput. *(Mathematics, applied)
Sichuan Daxue Xuebao
Studia Math.
Studia Sci. Math. Hungar
Tohoku Math. J.
Topology Appl.
Vychisl. Tekhnol.
Z. Anal. Anwendungen
Zap. Nauchn. Semin. POMI

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[15] Pierre Cartier, *Construction Combinatoire des Invariants de Vassiliev – Kontsevich des Nœds*, C. R. Acad. Sci. Paris Sér. I Math. **316, 11** (1993), 1205–1210, (not available via anonymous FTP).

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[17] J. Grabowski, G. Marmo, A. M. Perelomov, *Poisson structures: towards a classification*, Modern Phys. Lett. A **8** (1993), 1719–1733.

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Appendix C: List of Visitors

Program codes

The following codes indicate the programs which visitors attended.

AA: Mathematical problems of quantum gravity
AB: Mathematical relativity
AFG: Applications of integrability
AS: Quaternionic and hyper Kähler manifolds,
BBB: Mathematical population genetics and statistical physics
BE: Mathematical relativity
BFG: Mathematical aspects of string theory
BK: Quantization, generalized BRS cohomology, and anomalies
BS: Condensed matter physics
BYN: Local quantum physics
CAP: Guest of Cap
CDM: Noncommutative differential geometry
COO: Functional analysis
DK: Gibbs random fields and phase transitions
DOB: Gibbsian random fields
FG: Spectral geometry and its applications
FWY: Quantum field theory on curved space time
GAL: Holonomy groups in differential geometry
GG: Topological, conformal and integrable field theory
GRO: Two dimensional quantum field theory
GRU: Number theory and physics I. Convexity
HAS: Complex analysis
HO: Schrödinger Operators
HU: Complex analysis
HYH: Schrödinger operators with magnetic fields
KAK: Representation theory
KGT: Duality, string theory, and M-theory
KGV: Developed turbulence
KSM: Ergodic theory and dynamical systems
KSW: Random walks
LIE: Stability matters (Symposium in honor of Elliott H. Lieb)
LMS: Confinement
MGM: Nonlinear Schrödinger and quantum-Boltzmann equations
MI: Differential geometry (1993)
MI: Guest of Michor (1994+)
MM: Field theory and differential geometry
MTK: Noncommutative geometry and quantum field theory, Feynman diagrams
NAR: Ergodicity in non-commutative algebras
OGK: Nonlinear theory of generalized functions
PGS: Nonequilibrium statistical mechanics
PPK: Algebraic groups, invariant theory, and applications
PVZ: Scattering theory
PW: Representation theory with applications to mathematical physics
RGK: Aspects of foliation theory in geometry, topology and physics
SBH: Reaction-diffusion equations in biological context
SCH: Guest of Schmidt
SFA: Guest of Alexeev
SFD: Guest of Dani
SFN: Guest of Neretin
SFO: Guest of Onishchik
SFT: Guest of Todorov
SFV: Guest of Vershik
SF: Senior Fellow
SLC: Hyperbolic systems with singularities
SM: Charged particle kinetics
TIG: Arithmetic, automata, and asymptotics
TOD: Number theory and physics II. Quantum Field Theory and the Statistical Distribution of Prime Numbers
TSU: Spinors, twistors and conformal invariants
UNM: Spaces of geodesics and complex structures in general relativity and differential geometry
VK: Geometry of nonlinear partial differential equations
WAM: Mathematical cosmology
YNG: Guest of Yngvason
ZEZ: Quantum measurement and information

List of visitors

A

Aaronson Jon, Tel-Aviv University Dept. of Mathematics;
06.08.1997–22.08.1997, SCH;

Abakumov Evgeny, Université de Marne-la-Vallée;
06.06.1999–14.06.1999, COO;

Abanov Alexandre G., University of Chicago James Franck Institute;
18.08.1995–23.08.1995, HO;
31.08.1995–21.09.1995, HO;

Abdallah Ben, Naotel, Université Paul Sabatie;
25.11.2001–02.12.2001, MGM;

Abou-Zeid Mohab, Imperial College of Science Technology and Medicine;
02.04.2000–09.04.2000, KGT;
12.11.2001–18.11.2001, BFG;

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Appendix D: Statistics

The budget figures 1993 – 2002

The column 'Budget' indicates the amount of money made available to the Erwin Schrödinger Institute by the Ministry of Science in each year. The figures in the column 'Programs and Visitors / ESI financed' refer to the scientific activities (programs and visitors) funded directly by ESI, and the last column contains the sums of all direct financial contributions to ESI visitor funding by outside sources and of the nominal figures reflecting visitors to ESI funded by outside sources.

BUDGETS			
	IN ATS		
	Budget	**Programs & Visitors ESI financed**	**Programs & Visitors externally financed**
1993	**9,500,000.00**	**4,100,000.00**	**400,000.00**
1994	**9,500,000.00**	**4,400,000.00**	**750,000.00**
1995	**10,600,000.00**	**4,700,000.00**	**1,380,000.00**
1996	**11,100,000.00**	**4,426,000.00**	**1,190,250.00**
1997	**9,600,000.00**	**3,756,750.00**	**1,120,000.00**
1998	**10,500,000.00**	**4,281,483.01**	**2,309,000.00**
1999	**10,740,000.00**	**5,021,534.99**	**2,150,000.00**
2000	**10,740,000.00**	**6,531,774.95**	**1,260,000.00**
2001	**10,740,000.00**	**7,481,838.33**	**1,537,000.00**
	IN EURO		
	Budget	**Programs & Visitors ESI financed**	**Programs & Visitors externally financed**
1993	**690,400.00**	**297,959.00**	**29,069.00**
1994	**690,400.00**	**319,760.00**	**54,505.00**
1995	**770,300.00**	**341,562.00**	**100,289.00**
1996	**806,700.00**	**321,650.00**	**86,499.00**
1997	**697,700.00**	**273,014.00**	**81,394.00**
1998	**763,100.00**	**311,148.00**	**167,802.00**
1999	**780,500.00**	**364,929.00**	**156,247.00**
2000	**780,500.00**	**474,683.00**	**91,568.00**
2001	**780,500.00**	**543,726.00**	**111,698.00**
2002	**780,700.00**		

Programs, visits and visitors, and preprints in each year

The first table gives an overview over the numbers of programs, conferences and workshops organized outside the main programs, visitors, countries of origin of the visitors, and preprints in each year. The subsequent tables give further details. The information for 2002 was last updated on October 15, 2002.

Year	Programs	Conferences	Visitors	Countries	Preprints
1993	3		103	18	67
1994	5	2	185	33	119
1995	6	3	217	34	108
1996	4	4	259	31	120
1997	5	2	242	34	105
1998	6	3	333	39	133
1999	5	2	409	42	168
2000	5	3	408	51	157
2001	5	3	460	41	137
2002	6	2	334	43	109

In the second table, the column 'ESI financed visits' contains the total number of individual ESI-sponsored visits by scientists each year. The column 'Externally financed visits' gives the number of visits of scientists funded by external sources. The last column gives the total number of visitors in each year.

Number of visits/visitors per year			
	ESI financed	Externally financed	
	Visits	Visits	Visitors
1993	85	31	103
1994	201	36	185
1995	215	49	217
1996	249	98	259
1997	221	104	242
1998	290	127	333
1999	415	76	409
2000	439	63	408
2001	473	115	460
2002	277	95	334
Total	2865	794	2950

The third table shows the average duration of visits, the number of individual visits exceeding two weeks in length, and the percentage of 'long' visits among the number of all visits.

Duration of visits per year			
	Average dur.	Long visits	Ratio of long
		> 14 days	Visits
1993	37.6	69	0.62
1994	22.5	102	0.46
1995	21.5	110	0.46
1996	19.6	153	0.54
1997	19.8	105	0.39
1998	17.5	118	0.32
1999	15.7	122	0.26
2000	16.7	134	0.29
2001	14.4	161	0.31
2002	15.0	103	0.28
Total	18.0	1177	0.35

The final table gives a breakdown of the countries of origin of our visitors in each year. The figures for Austrian visitors do not include local participants.

Countries											
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Afghanistan								1			1
Argentina		2	2	2	2	1	4	2		2	17
Armenia		1	1			2		2	1		7
Australia		2	2	3	2	2	2	10	9		32
Austria	4	9	6	11	7	11	13	21	16	15	113
Belarus					3	1		1	2		7
Belgium		4	3	1	1	6	5		5	3	28
Bosnia							1				1
Brazil		1	1	2	2	6	3	2	3	1	21
Bulgaria	6	3	3	6	2	12	9	2	15	3	61
Canada	4	6	6	4	3	5	11	4	12	5	60
Chile								1	2	1	4
China			1	2	3	2	4	13	9	1	35
Croatia		2						4		1	7
Czech Republic	6	7	8	7	4	5	22	21	4	10	94
Denmark		1	1	3		7	3	1	5	4	25
Ecuador									1		1
Finland			2		1	2	2	7		8	22
France	6	10	18	20	19	45	41	20	70	51	300
Germany	16	24	26	38	41	47	73	53	49	57	424
Great Britain	2	14	7	4	18	13	19	21	18	11	127
Greece				1	1	3	3	6	2	1	17
Hungary	1	8	11	7	8	5	14	6	10	7	77
Iceland		1	1	2		1		2			7
India			2	1		3	1	14	10	4	35
Ireland		1			3	1	1	3		3	12
Israel	3	4	4	2	7	12	10	14	7	11	74
Italy	13	15	21	32	15	29	54	20	44	25	268
Japan		4	7	5	8	8	9	9	13	9	72
Kazachstan						1		1		1	3
Korea		2			6			1	4	1	14
Lebanon			2								2
Lithuania							1			2	3
Luxembourg						2					2
Mexico			1					1			2
Morocco						1	1	1			3
Myamar								2	2		4
Netherlands		1	2	5	5	6	1	8	7	3	38
New Zealand					3	2	1	1	1	1	9
Norway		1	1		3		3	2	2	1	13
Poland	4	18	12	8	19	6	17	24	14	9	131
Portugal				1		1		1		1	4
Romania	5	4	4			2	8	2	2	2	29
Russia	23	29	31	47	20	40	48	64	69	21	392
Serbia								6			6
Slovakia	3	6	8	4			3	3	1	1	29
Slovenia							1				1
South Africa									1		1
Spain	1	2	3	5	2	7	7	7	10	2	46
Sri Lanka								1			1
Sweden		3	3	2	1	5	7	5	14	3	43
Switzerland	5	7	6	6	3	10	7	7	10	15	76
Taiwan							2	2		1	5
Tunesia							3	1	6	3	13
Turkey										1	1
USA	9	22	28	37	48	54	43	52	62	48	403
Ukraine	1	8	7	12	5	5	5	4	6	1	54
Uruquay				2	1				1	1	5
Uzbekistan						1	1	1	1		4
Venezuela								1			1
Yugoslavia					3		2	5		1	11
Zimbabwe		1					1		1		3