

Scientific Report for the Year 2002

Vienna, ESI-Report 2002

March 1, 2003

Supported by Federal Ministry of Education, Science, and Culture, Austria

**ERWIN SCHRÖDINGER INTERNATIONAL INSTITUTE
OF MATHEMATICAL PHYSICS,
SCIENTIFIC REPORT FOR THE YEAR 2002**

ESI, Boltzmanngasse 9, A-1090 Wien, Austria,

March 1, 2003

Honorary President: Walter Thirring, Tel. +43-1-4277-51516.

President: Jakob Yngvason: +43-1-4277-51506. yngvason@thor.thp.univie.ac.at

Director: Peter W. Michor: +43-1-3172047-16. Peter.Michor@esi.ac.at

Director: Klaus Schmidt: +43-1-3172047-14. Klaus.Schmidt@univie.ac.at

Administration: Maria Windhager, Eva Kissler, Ursula Sagmeister: +43-1-3172047-12,
secr@esi.ac.at

Computer group: Andreas Cap, Gerald Teschl, Hermann Schichl.

International Scientific Advisory board:

Jean-Pierre Bourguignon (IHES),

Luis A. Caffarelli (Austin, Texas),

Giovanni Gallavotti (Roma),

Krzysztof Gawedzki (IHES),

Viktor Kac (MIT),

Elliott Lieb (Princeton),

Harald Grosse (Vienna),

Harald Niederreiter (Vienna),

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General remarks

In the year 2002 ESI was host to 433 visitors. There were 146 preprints contributed to the preprint series (164 till mid-February), some of them still belong to programs from earlier years, 355 seminar talks or ESI-Colloquia were given outside of conferences, many more lectures were given in conferences at ESI.

ESI has spent E 409.943,- for science which was supplemented by E 282.875,- of foreign support; E 351.346,- were spent for administrative costs including renting the premises and personnel cost.

In November and December ESI was subject of a scientific review which was set up in the following way: After consulting the Federal Ministry of Education, Science, and Culture who promised to pay part of the expenses, J.-P. Bourguignon, director of IHES in Bures-sur-Yvette and member of the scientific advisory committee of ESI, was asked on the behalf of the board of ESI (Vorstand des Vereines) to organize a review panel of 5 leading scientists and to appoint its chairman. This was done, the report of the review panel is included in this report, see the next nine pages.

From the preprint server <http://www.esi.ac.at/Preprints> 14438 preprints were downloaded during the year 2002 (January 1037, February 1124, March 1294, April, 950, May 1084, June 907, July 1090, August 802, September 965, October 2740, November 1406, December 1040) For comparison, in 1998 we had 7011 downloads, in 1999 15845, and in 2000 14356, and in 2001 16127.

The following conferences were (co)organized by ESI:

- (1) **The 22th Winter school on geometry and physics**, January 12 – 19, 2002, in Srni, a small village in the Bohemian forest, Czech republic.
- (2) **Arithmetic Groups and Automorphic Forms**, January 27 – February 2, 2002, ESI, Vienna.
- (3) **Stability Matters:** A Symposium on Mathematical Physics in honor of Elliott H. Lieb on the occasion of his 70th birthday. July 28 – August 2, 2002.

Many workshops and conferences were organized inside the current programs of 2002.

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

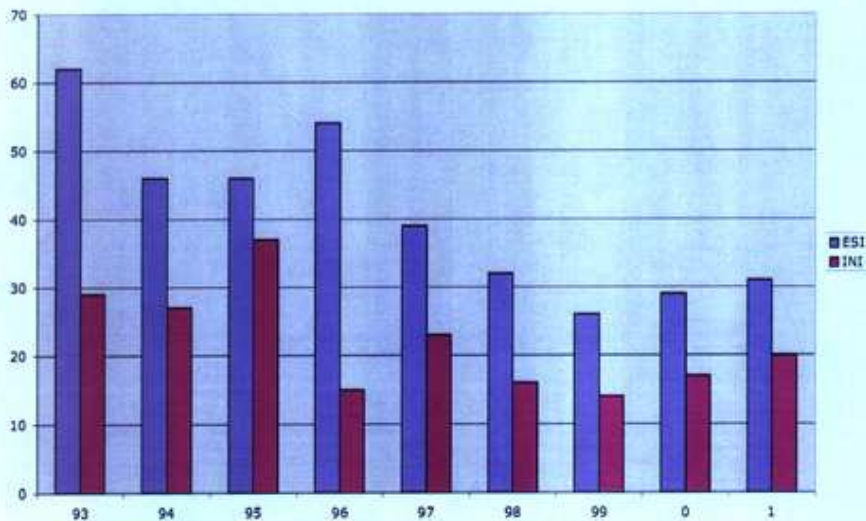
The ESI was founded in the early 1990's to provide "a focal point for both Eastern and Western science and an international platform at the highest level of research". This mission was strongly influenced by the desire to aid the scientific community in the former communist countries of Eastern Europe, 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.

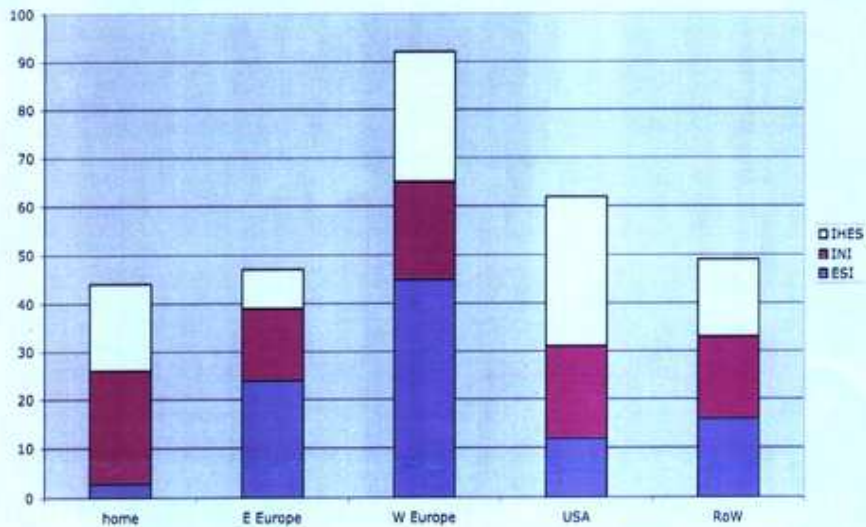
After nearly ten years the ESI has gained a recognized position amongst the research institutes in mathematics and physics in Europe by building upon the scientific tradition of Vienna in the fields of mathematics and physics and the cultural tradition and the regional contacts in Central Eastern Europe. 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

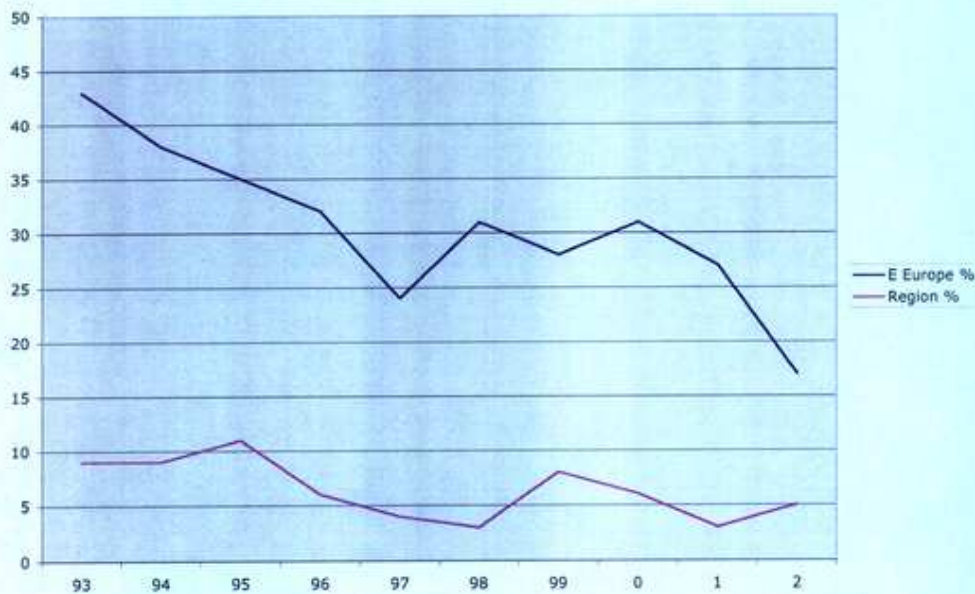


Visitor profile



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.

Eastern Europe and the Region



§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

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§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 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

Winter School in Geometry and Physics

The traditional winter school in geometry and physics which takes place for one week each January since 1980 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. Usually there are proceedings, which are published as a supplement of the 'Rendiconti Matematici di Palermo'.

In this year, the 22th Winter school on Geometry and Physics took place in the week January 12–19, 2002. ESI has contributed E 1.000,-.

Arithmetic Groups and Automorphic Forms

January 27 – February 2, 2002, organized by Joachim Schwermer (University of Vienna). This workshop was financed with E 11.100,- through the share of K. Schmidt, foreign support was E 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 on the occasion of his 70th birthday

July 28 - August 2, 2002. Organized by Thomas Hoffmann-Ostenhof, Harald Grosse, Heide Narnhofer, Klaus Schmidt, Walter Thirring, and Jakob Yngvason. ESI contributed E 300,-, foreign support was E 30.525,-.

Parts of the conference were also: Decoration ceremony for Elliott H. Lieb (Goldenes Bundesverdienstkreuz für Wissenschaft und Kunst) in the Audienzsaal of the Ministry for Science, Culture and Education, Minoritenplatz 5.

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. Erdős: 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.

PROGRAMS IN 2002

Developed Turbulence

Organized by K. Gawedzki, A. Kupiainen and M. Vergassola. 27.3 man/months allocated.
 ESI contributed E 55.815,-, foreign support was E 1.875,-.

11 Preprints: [1176], [1179], [1180], [1181], [1190], [1192], [1197], [1213], [1224], [1230], [1276].

Initials: KGV

May 15 to July 14, 2002.

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 61700 euro. 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.

Krzysztof Gawędzki
ENS-Lyon
kgawedzk@ens-lyon.fr

Antti Kupiainen
Dept. of Math., Helsinki U.
ajkupiaini@cc.helsinki.fi

Massimo Vergassola
Observatoire de Nice
massimo@obs-nice.fr

Invited Scientists: Nikolai Antonov, Heikki Arponen, Erik Aurell, Bauer Michel, Jeremie Bec, Denis Bernard, Luca Biferale, Mikhail Blank, Yann Brenier, Jean Bricmont, Antonio Celani, Massimo Cencini, Marie-Line Chabanol, Mikhael Chertkov, Sergio Ciliberto, Colm Connaughton, Peter Constantin, Thierry Dombre, Jean Duchon, Bérengère Dubrulle, Gregory Eyink, Gregory Falkovich, Albert Fannjiang, Uriel Frisch, Christophe Giraud, Ville Hakulinen, Péter Horvai, Konstantin Khanin, Tomasz Komorowski, Susan Kurien, Antti Kupiainen, Yves Le Jan, Emmanuel Leveque, Detlef Lohse, Jani Lukkarinen, Nader Masmoudi, Andrea Mazzino, Keith Moffat, Mojens Hogh Jensen, Paolo Muratore-Ginanneschi, Stefano Musacchio, Sergey Nazarenko, Alan C. Newell, Piero Olla, George Papanicolaou, Walter Philipp, Alan Pumir, Olivier Raimond, Alexander Shnirelman, Yakov Sinai, Meir Smorodinsky, Andrey Sobolevskiy, Victor Steinberg, Eric Vanden Eijnden, John Christos Vassilicos, Massimo Vergassola, Emmanuel Villermaux, Dario Vincenzi, Angelo Vulpiani, Jan Wehr, E Weinan, Vladimir Zakharov.

Transcription of the Web-page of the Program on Developed Turbulence:.

Organizers:

Krzysztof Gawędzki, Ecole Normale Supérieure, Lyon, France
Antti Kupiainen, Dept. of Mathematics, Helsinki University, Finland
Massimo Vergassola, CNRS, Observatoire de la Côte d'Azur, France

Developed Turbulence: a problem with many faces

Objectives of the Program

Workshop on Burgers Turbulence and Beyond

Clay Mathematics Institute support

List of Participants

Schedule of visits

Seminar program: Burgers week, then weekly program.

The variety of irregular phenomena accompanying flows in liquids and gases is usually encoded in the single term of turbulence. Turbulent flows are omnipresent. They occur in oceans and in the atmosphere, in industrial processes and in an astrophysical context. Turbulence is the most striking manifestation of the non-linear nature of the laws of hydrodynamics, with the irregularity of flows increasing with the Reynolds number measuring the strength of non-linear effects. The regime of intermediate Reynolds numbers corresponds to a highly nonuniversal regime of the onset of turbulence, whereas high Reynolds numbers, common in practical situations, characterize the regime of developed turbulence. The latter shows many general aspects that are common to different flows (statistical symmetries, persistent dissipation, energy cascade, intermittency) supporting the hope that they may be explained in a uniform way. Despite those universal features, the understanding of developed turbulence has entered the third millennium as one of the great unsolved conceptual problems, on the borderline between mathematics and physics, with numerous ramifications from astrophysics through meteorology to engineering. The practical importance of such an understanding that would lead to a better control of turbulence, permitting to enhance its desired effects (like the turbulent mixing) and to decrease its adverse influence (like the turbulent drag), can hardly be overstated.

On the mathematical side, the problem concerns the behavior of solutions of the hydrodynamical equations describing the time evolution of the velocities and, possibly, other quantities like density, temperature, magnetic field, etc. The simplest example is the almost two century

old Navier-Stokes equations. Despite a long study, the open questions abound here. Let us mention only the best known problem, one of the seven Millennium Prize Problems of the Clay Mathematics Institute, about the global existence of solutions for smooth initial data, a genuine high Reynolds number problem. Different variations of hydrodynamical equations describe variety of physical phenomena (turbulent transport or diffusion, environmental dispersion, combustion, multiphase flows, geophysical and astrophysical flows etc.) and their mathematical study, besides common features, poses specific problems.

On the physical side, one usually deals with questions about the statistical properties of the flows, in particular, about the decay of a turbulent statistical state or about existence and properties of steady states maintained by continuously stirring the fluid. Such states are observed experimentally (e.g. in wind tunnels or water jets) and they seem to be characterized by non-vanishing fluxes of energy and other conserved quantities, a typical feature of non-equilibrium situations. The high Reynolds number turbulent states are strongly coupled and defy analytic approaches which proved successful in the equilibrium statistical mechanics, like the perturbative expansions and/or the renormalization group analysis. The statistics of such quantities as the velocity or temperature differences is highly non-Gaussian at short distances, as signaled by the spatial and the temporal intermittency of signals measured in natural flows, in experiments and in numerical simulations. The detailed mechanism of intermittency remains to be understood, despite many quasi-phenomenological models. An analytic control of the turbulent states remains still an elusive goal.

An important progress has been achieved in the last decade in understanding some simpler systems exhibiting behaviors similar to developed turbulence. These include the so-called weak or wave turbulence, the advection of passive scalar and vector fields by random velocities that mimic the turbulent ones, and, to certain extent, the so-called Burgulence, the phenomena described by the Burgers equation.

Weak turbulence concerns the behavior of a spatially homogeneous ensemble of weakly interacting dispersive waves and occurs in several Hamiltonian PDE's, like the nonlinear Schrödinger equation. These Hamiltonian systems, once driven by external sources, exhibit non-equilibrium steady states with nonzero fluxes of conserved quantities (energy and particle number in the case of the Schrödinger equation). The difference with the "strong turbulence" of the Navier-Stokes equation is that the weakly turbulent state is accessible via perturbation theory in the strength of the adjustable nonlinear coupling constant which is absent in the case of strong turbulence.

Examples of passively advected quantities are the temperature or the impurity concentration in a fluid. Ideally one would be interested in the statistical properties of the advected field in the case where the underlying flow is turbulent. Significant progress has been achieved when the velocity field is taken random, with Gaussian statistics but decorrelated (white) in time. One mimics the important feature of turbulent flows by taking the velocities rough, i.e. only Hölder continuous, in space. For such an ensemble of velocities (called the Kraichnan model), it was possible to study the ensuing steady state of the advected fields both analytically and numerically. It appears to be a nonequilibrium state with nonzero flux of a conserved quantity, again in analogy to hydrodynamical turbulence. Moreover it exhibits intermittency in the form of anomalous scaling of moments of scalar differences in nearby points, the first (and so far only) nontrivial model where the anomalous scaling has been established analytically.

The Burgers equation is a pressureless version of the Navier-Stokes equation. Its 1-dimensional version, in particular, has been extensively studied. When randomly stirred, it exhibits the energy cascade with the short-distance dissipation dominated by the shock-like structures and strong intermittency.

Although good quantitative experimental measurements and numerical simulations involving developed turbulence are notoriously difficult, there has been a considerable progress on that side as well and new sets and types of data become available. As for experiments, optical non-intrusive methods start to give access to the multi-point structure of turbulent flows. The importance of multi-point objects is one of the key lessons that emerged from theoretical studies in the past few years. Going beyond structure functions will also permit to highlight the presence and the role of coherent structures. Another fast developing experimental tool is the particle-tracking technique, whose aim is to follow fluid particles and hence give information

on the Lagrangian velocity statistics. Both types of experiments are strongly coupled with the theoretical issues of current debate in the turbulence community. Numerical simulations are natural candidates to permit the resolution of the whole velocity field and of the Lagrangian and multi-point statistics, although at more limited Reynolds numbers.

The objective of the program that we organize at ESI is to provide an opportunity for collaboration and exchange of ideas between experts in the turbulence related fields, mathematicians working on the hydrodynamical PDE's and physicists interested in the statistical aspects of turbulence, in order to induce a fruitful interaction as well as to chart ways of proceeding beyond the simple models of turbulent states. A number of experimentalists will also take part. Both experiments and numerical simulations continue to provide an essential input without which conceptual progress in understanding turbulence would be impossible. On the other hand, such progress suggests new questions that can be submitted to experimental and numerical verification. Hence the importance of the permanent exchanges between theorists and practitioners in the field. The program will create another possibility for such a contact. If expecting major breakthroughs in the reputedly hard fundamental theoretical questions might not be realistic, we are expecting to see progress in the following directions:

An important role in the practical control of turbulence is played by simplified non-linear dynamical systems modeling the turbulent evolution of few selected degrees of freedom (e.g. the strain and vorticity). Confronting the data from such models with the theoretical ideas and the real turbulence data should lead to further improvements in this type of modeling. Although perturbative analysis of weak turbulence has been performed for several models, the rigorous results are scarce. It seems, that a lot can be learned by perfecting the mathematical theory of the corresponding equations (e.g. by exhibiting cascade-like tendencies in the evolution of the energy spectrum of individual solutions). One of the general lessons from the study of the passive advection is that the turbulent states which occur there are supported on dissipative weak solutions of the corresponding PDE in the zero diffusivity limit. It seems then important to better understand the role of such weak solutions in the nonlinear models. The persistence of dissipation in the zero viscosity limit is related to a striking property of nonuniqueness of fluid trajectories in rough velocity fields. Up to now, the phenomenon was studied in detail only in simple synthetic ensembles of velocities statistically decorrelated in time. It is important to understand the nonuniqueness question in the case of time correlated velocity fields. It will be also important to design more penetrating tests of that behavior in real flows. Intermittency in the passive advection was shown to be related to zero modes of the effective generators of the multi-trajectory processes. Such zero modes seem to be present in the realistic turbulent ensembles but their role there still remains to be understood. One of the important questions is their relation to the spatio-temporal structures observed in the flows. In general, the program should stimulate experiments and numerical simulations aimed at extending the, presently insufficient, Lagrangian and multi-point information about realistic flows. Although the free decay of solutions of the Burgers equation in one dimension has been studied extensively, the results about the forced case and higher dimensions are much less complete and it seems that further progress here is not beyond reach.

ESI Workshop on Burgers Turbulence and Beyond (BTB6). May 27-31 (organized by Uriel Frisch and Yasha Sinai)

SCIENTIFIC 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 and real turbulence
 Discussion on Burgers and applications (with a coffee break : around 15:30)
 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 (with a coffee : break around 15:30)
 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
 Final discussion.

Clay Mathematics Institute support: Five U.S.-based scientists will participate in the Program as emissaries of the Clay Mathematics Institute.

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.

Latest update on 5/07/2002.

Arithmetic, automata, and asymptotics

R. Tichy and P. Grabner, spring, 35 man/months.
 ESI contributed E 38.811,-, foreign support was E 2.025,-.
 6 ESI preprints: [1158], [1160], [1161], [1184], [1187], [1218].
 Initials: TIG

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.

Arithmetics and Automata. The workshop on Arithmetics and Automata was held in Graz. The workshop was devoted to recent developments in the interplay between number theory, automata theory, and ergodic theory.

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. Györy (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. The research conference on Algorithms and Asymptotics was held in Graz. Topics from number theory, asymptotic combinatorics, and ergodic theory were the theme of this conference.

- 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. Sarkózy (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) Syntactic 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. Györy (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'rkózy, 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

K. Fredenhagen, R. Wald and J. Yngvason, July-August, 18.4 man/months allocated.

ESI contributed E 44.625,-, foreign support was E 4.124.-.

20 ESI-preprints: [1121], [1149], [1156], [1157], [1163], [1164], [1183], [1185], [1186], [1196], [1198], [1199], [1202], [1204], [1205], [1208], [1215], [1233], [1246], [1248].

Initials: FWY

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 the following 5 topics:

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

Invited Scientists: Abhay Ashtekar, Martin Bojowald, Romeo Brunetti, Detlev Buchholz, Claudio D’Antoni, Stephen Fairhurst, Christopher Fewster, Eanna Flanagan, Larry Ford, Klaus Fredenhagen, Rodolfo Gambini, Daniele Guido, Stefan Hollands, Theodore A. Jacobson, Wolfgang Junker, Bernd Kuckert, Muharrem Küskü, Fernando Lledó, Jerzy Lewandowski, Alejandro Perez, Michael Pfenning, Jorge Pullin, Karl-Henning Rehren, Thomas A. Roman, Hanno Sahlmann, Thomas Thiemann, William G. Unruh, Rainer Verch, Robert Wald.

Aspects of foliation theory in geometry, topology and physics

Franz W. Kamber (Principal Organizer), James F. Glazebrook, Kenneth Richardson, Peter W. Michor (Local Coordinator). Mid-July – December, 35.1 man/months

ESI contributed E 76.875,-, foreign support was E 52.500,-

18 ESI preprints: [1188], [1189], [1207], [1211], [1212], [1219], [1222], [1223], [1225], [1244], [1245], [1249], [1252], [1266], [1267], [1268], [1270], [1278].

Initials: RGK

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 Tunisia. Within the constraints of the budget, we invited young researchers, mainly on the suggestion of senior participants.

While most principal 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 EUR 79,000. We were fortunate to be able to augment the program budget from several sources. Prof. Peter Michor, Scientific Director of ESI, made a generous contribution in the form of visitor appointments 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 EUR 100,000.

According to the financial statement by the ESI Administration and our own records, the residual balance of ESI funds is EUR 4274. We would like to request that these funds be made available for a small follow-up activity in 2003. The idea is to invite a few workgroups in order to continue, respectively complete projects started during the program.

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.

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.

4. 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.

5. 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 enthusiastically 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 EUR 3250. Participant contributions were about EUR 1000 for a net expenditure of EUR 2250 from ESI funds, which was within budget.

James F. Glazebrook and Franz W. Kamber: Department of Mathematics, University of Illinois Urbana-Champaign, 1409 West Green Street, Urbana, IL 61801, USA,
Phone +1-217-333-2699 / FAX +1-217-333-9576, glazebro@math.uiuc.edu , kamber@math.uiuc.edu

Ken Richardson: Department of Mathematics, Texas Christian University, Box 298900, Fort Worth, TX 76129, USA.
Phone +1-817-257-6128, k.richardson@tcu.edu

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 Brüning, 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

H. Grosse, J. Madore and J. Mickelsson; D. Kreimer and I. Todorov; fall, 35.1 man/months
ESI contributed E 63.450,-, foreign support was E 5.625,-.

17 ESI preprints: [1138], [1193], [1201], [1217], [1220], [1221], [1227], [1228], [1229], [1231], [1232], [1236], [1237], [1239], [1251], [1258], [1271].

Initials: MTK

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 experience 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 theories 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 concerned 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 general 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 theories and the Dijkgraaf-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.

Harald Grosse, John Madore, Jouko Mickelsson, Dirk Kreimer, Ivan Todorov

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 Prešnjajder, 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

E. Baake, M. Baake and R. Bürger, late fall, 13.3 person-months in 2002, (14 in 2003).

ESI contributed E 26.775,-, foreign support was E 9,075,-.

11 ESI preprints: [1247], [1250], [1255], [1257], [1260], [1261], [1265], [1274], [1275], [1277], [1279].

Initials: BBB

This program is still going on, so the report will done 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, Ilijana Zähle.

CONTINUATION OF PROGRAMS FROM 2001 and earlier

Nonequilibrium Statistical Mechanics. Continuation of a program from 1999. Organized by G. Gallavotti (Rome), H. Spohn (München), and H. A. Posch (Vienna).

In 1999: ESI contributed 509,000.-, foreign support was AS 21,000.-.

In 2000: ESI AS 6,000.-.

In 2001: ESI contributed AS 194,122.-, foreign support AS 5.000.-.

Altogether: ESI contributed AS 709,000.-, foreign support was AS 21,000.-.

15 ESI-preprints: 1999: [659], [675], [684], 2000: [843], [844], 2001: [1113] 2002: [1143], [1144], [1145], [1146], [1147], [1148], [1151], [1152], [1153], [1269].

Quantum Measurement and Information. Continuation of a program organized by Anton Zeilinger (Wien), Arthur Eckert (Oxford), Peter Zoller (Innsbruck), Sept. - Dec. 2000. No ESI contribution. 8 ESI-preprints: [981], [988], [1006], [1019], [1035], [1036], [1041], [1080], Altogether: ESI contributed AS 990,000.-, foreign support was AS 200,000.-. 16 ESI-preprints.

Functional Analysis. Continuation of a program from 1999. Organized by James B. Cooper, Paul F.X. Müller, Michael Schmuckenschläger, and Charles Stegall. ESI contributed 16,154.-. 9 ESI-preprints: [1005], [1007], [1008], [1012], [1013], [1014], [1020], [1031], [1060]. Altogether, in 3 years: AS 1,017,154.- from ESI, foreign support AS 770,500.-, 52 ESI preprints.

Scattering Theory. Continuation of a program from 2001. Organized by Vesselin Petkov, András Vasy, and Maciej Zworski. ESI contributed AS 980,000.-, foreign support was AS 208.000.-. 8 ESI-preprints: [1040], [1044], [1048], [1052], [1067], [1068], [1073], [1091].

Random Walks. Continuation of a program from 2001. Organized Vadim Kaimanovich, Klaus Schmidt and Wolfgang Woess ESI contributed AS 1,091,155.-, foreign support was 647,750.-. 37 ESI-preprints: [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].

Mathematical Cosmology. Continuation of a program from 2001. Organizers: P.C. Aichelburg, G.F.R. Ellis, V. Moncrief, J. Wainwright. ESI contributed AS 468.853.-, foreign support was AS 9,000.-. 11 ESI-preprints: [1057], [1117], [1119], [1120], [1122], [1123], [1136], [1137], [1140], [1141], [1156].

Mathematical Aspects of String Theory. Continuation of a program from 2001. Organized by Matthias Blau, Figuera O'Farril, Greens, Albert Schwarz, Helmuth Urbantke. No visitors in 2001. ESI contributed AS 821,000.-, no foreign support. 18 ESI-preprints: [1087], [1090], [1096], [1099], [1100], [1102], [1103], [1104], [1106], [1116], [1118], [1126], [1129], [1162], [1193], [1194], [1195], [1220].

SENIOR FELLOWS and GUESTS via Director's shares

Yurii A. Neretin. January 1 – February 28, 2002. ESI contribution E 9.574.-. ESI preprints [1124], [1130], [1165], [1262].

Ivan Todorov. ESI contribution E 10.000.-. ESI preprints: [1131], [1132], [1155], [1242], [1243].

Invited Scientists: Bojko Bakalov, Ludmil Hadjiivanov, Nikolay Mitov Nikolov.

Shrikrishna G. Dani. ESI contribution E 10.000,-. ESI-preprints: [1050], [1182], [1191].

Invited Scientists: Yves Guivarch, Michael McCrudden.

Anatoli Vershik. ESI contribution E 6.000,-. [1234], [1254].

Invited Scientists: Anna Erschler, Alexandre Gorboulski.

He also gave one of the **ESI Senior Research Fellows Advanced Graduate Lectures Series** which were supported by the University of Vienna, on **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 - November 2002.

Arkadi Onishchik. ESI contribution E 7.500,-. ESI preprint: [1253].

Invited Scientists: Mikhail Bashkin, Vladimir Gorbatsevich.

He also gave one of the **ESI Senior Research Fellows Advanced Graduate Lectures Series** which were supported by the University of Vienna, on **Real Forms and Representations**, on Tuesdays, 15.30-17.00, ESI lecture hall October 8, 2002 - December 20, 2002. 12 students and faculty were present during the lecture. The lecture will be published as ESI Lecture Notes.

Content:

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.

Guests of Jakob Yngvason. ESI share E 27.747,85, foreign support E 1.125,-. See the report on the program 'Quantum field theory on curved space time' above.

Invited Scientists: Dmitri Vasilevich, Hans-Jürgen Borchers, Elliott Lieb, Luiz Alberto Manzoni, Bert Schroer.

Guests of Klaus Schmidt. ESI share E 18.665,59, foreign support E 139.550,-. ESI-preprints: [1125], [1127], [1128], [1134], [1203], [1216], [1256], [1259], [1263], [1264], [1272].

Invited Scientists: Siddhartha Bhattacharya, Geon Ho Choe, Moshe, Eli Glasner, Vadim Kaimanovich, Robert Langlands, David Masser, Byoung Ki Seo.

Guests of Peter Michor. ESI share E 3.650,-, foreign support E 33.750,-. ESI-preprints: [1138], [1139], [1154], [1166], [1200], [1214], [1225], [1235].

Invited Scientists: 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 F. Haslinger. ESI-preprints: [1175], [1206], [1210], [1273].

Guests of A. Cap. ESI share E 1.725,-, foreign support E 150,-. ESI-preprints: [1177], [1178].

Invited Scientists: Rod A. Gover, Jan Slovák, Vladimir Souček.

Guests of Th. Hofmann-Ostenhof. ESI-preprints: [1142], [1238], [1240], [1241]

Guests of W. Kummer. ESI-preprints: [1159].

List of Preprints in 2002

We try to keep track of the bibliographical data of the published versions of the preprints – this is very incomplete and we are trying to update it. The most complete list can always be found on the ESI server <http://www.esi.ac.at/ESI-Preprints.html>.

- 1116. Albert Schwarz, *Gauge Theories on Noncommutative Euclidean Spaces* (2002), 9 pp..
- 1117. Piotr Bizoń, Arthur Wasserman, *On the Existence of Self-Similar Spherically Symmetric Wave Maps Coupled to Gravity* (2002), 15 pp..
- 1118. Matthias Blau, José Figueroa-O'Farrill, Christopher Hull, George Papadopoulos, *Penrose Limits and Maximal Supersymmetry* (2002), 12 pp..
- 1119. Marco Bruni, Cristiano Germani, Roy Maartens, *Gravitational Collapse on the Brane* (2002), 5 pp..
- 1120. Marco Bruni, Filipe C. Mena, Reza Tavakol, *Cosmic No-Hair: Non-Linear Asymptotic Stability of de Sitter Universe*, *Classical Quantum Gravity*, 5 pp. (to appear).
- 1121. Volker Bach, Frédéric Klopp, Heribert Zenk, *Mathematical Analysis of the Photoelectric Effect* (2002), 39 pp..
- 1122. Christiane Lechner, Jonathan Thornburg, Sascha Husa, Peter C. Aichelburg, *A New Transition between Discrete and Continuous Self-Similarity in Critical Gravitational Collapse* (2002), 4 pp..
- 1123. Greg Huey, Reza Tavakol, *Robustness of the Quintessence Scenario in Particle Cosmologies*, *Phys. Rev. D*, 28 pp. (to appear).
- 1124. Yu.A. Neretin, *Action of Overalgebra in Plancherel Decomposition and Shift Operators in Imaginary Direction* (2002), 11 pp..
- 1125. B. Krön, *Growth of Self-Similar Graphs* (2002), 14 pp..
- 1126. Yoshihisa Kitazawa, *Vertex Operators in IIB Matrix Model* (2002), 21 pp..
- 1127. Siddhartha Bhattacharya, Klaus Schmidt, *Homoclinic Points and Isomorphism Rigidity of Algebraic Z^d -Actions on Zero-Dimensional Compact Abelian Groups* (2002), 16 pp..
- 1128. Siddhartha Bhattacharya, *Higher Order Mixing and Rigidity of Algebraic Actions on Compact Abelian Groups* (2002), 12 pp..
- 1129. Ilka Agricola, *Connections on Naturally Reductive Spaces, their Dirac Operator and Homogeneous Models in String Theory* (2002), 25 pp..
- 1130. Yurii A. Neretin, *A Construction of Finite-Dimensional Faithful Representation of Lie Algebra* (2002), 2 pp..
- 1131. Dmitry Leites, *On Unconventional Integrations and Cross Ratio on Supermanifolds* (2002), 9 pp..
- 1132. Dmitry Leites, *The Riemann Tensor for Nonholonomic Manifolds* (2002), 8 pp..
- 1133. Nikolai L. Gordeev, Vladimir L. Popov, *Automorphism Groups of Finite Dimensional Simple Algebras*, *Ann. of Math.*, 22 pp. (to appear).
- 1134. Klaus Schmidt, *Dispersing Cocycles and Mixing Flows Under Functions*, *Fund. Math.* **173** (2002), 191–199.
- 1135. Martin Bojowald, Thomas Strobl, *Poisson Geometry in Constrained Systems* (2002), 41 pp..
- 1136. Lars Andersson, Vincent Moncrief, *Elliptic-hyperbolic systems and the Einstein equations* (2002), 30 pp..
- 1137. G.F.R. Ellis, P. McEwan, W. Stoeger, P. Dunsby, *Causality in Inflationary Universes with Positive Spatial Curvature* (2002), 14 pp..
- 1138. Roland Berger, Michel Dubois-Violette, Marc Wambst, *Homogeneous Algebras* (2002), 24 pp..
- 1139. Andreas Kriegl, Mark Losik, Peter W. Michor, *Tensor Fields and Connections on Holomorphic Orbit Spaces of Finite Groups* (2002), 15 pp..
- 1140. G. Ellis, *Dynamical Properties of Space of Space-Times* (2002), 11 pp..
- 1141. G.F.R. Ellis, W. Stoeger, P. McEwan, P. Dunsby, *Dynamics of Inflationary Universes with Positive Spatial Curvature* (2002), 9 pp..
- 1142. S. Fournais, M. Hoffmann-Ostenhof, T. Hoffmann-Ostenhof, T. Østergaard Sørensen, *On the Regularity of the Density of Electronic Wavefunctions*, *Contemp. Math.*, 7 pp. (to appear).
- 1143. Giovanni Gallavotti, Fabio Perroni, *An Experimental Test of the Local Fluctuation Theorem in Chains of Weakly Interacting Anosov Systems* (2002), 15 pp..
- 1144. Giovanni Gallavotti, *Large Deviations, Fluctuation Theorem and Onsager-Machlup Theory in Nonequilibrium Statistical Mechanics*, withdrawn by the author, Not available via anonymous FTP.
- 1145. Christian Maes, Evgeny Verbitskiy, *Large Deviations and a Fluctuation Symmetry for Chaotic Homeomorphisms* (2002), 14 pp..
- 1146. Christian Maes, Karel Netočný, *Time-Reversal and Entropy* (2002), 38 pp..
- 1147. E.G.D. Cohen, L. Rondoni, *Particles, Maps and Irreversible Thermodynamics*, *Phys. A*, 20 pp. (to appear).
- 1148. L. Rondoni, G.P. Morriss, *On the Observability of Large Fluctuations* (2002), 22 pp..
- 1149. Elliott H. Lieb, Jakob Yngvason, *The Mathematical Structure of the Second Law of Thermodynamics* (2002), 35 pp..
- 1150. S.G. Dani, *Some Two-Step and Three-Step Nilpotent Lie Groups with Small Automorphism Groups* (2002), 14 pp..
- 1151. L. Rondoni, E.G.D. Cohen, *On some Derivations of Irreversible Thermodynamics from Dynamical Systems Theory* (2002), 24 pp..

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 Alekseev Anton, University of Geneva, Section of Mathematics; 19.11.2002 - 24.11.2002, SF;
 Alekseevsky Dmitri, Hull University; 20.01.2002 - 28.01.2002, MI; 13.12.2002 - 26.12.2002, MI;
 Allouche Jean-Paul, Université Paris-Sud, LRI, CNRS, Bat. 430; 24.06.2002 - 30.06.2002, TIG; 01.07.2002 - 07.07.2002, TIG;
 Alvarez-Consul Luis, University of Bath, Mathematical Sciences; 11.11.2002 - 30.11.2002, RGK;
 Antonov Nikolai, St. Petersburg University; 24.06.2002 - 14.07.2002, KGV;
 Arai Asao, Hokkaido University, Department of Mathematics; 29.10.2002 - 05.11.2002, MTK;
 Arponen Heikki, Helsinki University, Department of Mathematics; 01.07.2002 - 05.07.2002, KGV;
 Aschieri Paolo, L.M.U.; 01.10.2002 - 13.10.2002, MTK;
 Ashtekar Abhay, Pennsylvania State University, Center for Gravitational Physics and Geometry; 29.07.2002 - 20.08.2002, FWY;
 Aurell Erik, Swedish Institute of, Computer Science; 28.05.2002 - 31.05.2002, KGV;
 Avron Joseph, Technion, Dept. of Physics; 29.07.2002 - 02.08.2002, LIEB;
 Baake Ellen, Universität Greifswald, Institut für Mathematik; 01.12.2002 - 31.12.2002, BBB;
 Baake Michael, Universität Greifswald, Institut für Mathematik; 28.07.2002 - 01.08.2002, LIEB; 01.12.2002 - 31.12.2002, BBB;
 Badura Marek, University of Lodz, Faculty of Mathematics; 12.08.2002 - 17.08.2002, RGK;
 Bahns Dorothea, II. Institut für Theoretische Physik, Universität Hamburg; 04.10.2002 - 13.10.2002, MTK;
 Bakalov Bojko, University of California; 12.12.2002 - 31.12.2002, SFT;
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 Vasilevich Dmitri, Institut fuer Theoretische, Physik, Universitaet Leipzig; 06.01.2002 - 20.01.2002, YNG;
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 Baxa Christoph, Universität Wien, Institut für Mathematik; 25.06.2002 - 30.06.2002, TIG; 01.07.2002 - 05.07.2002, TIG;
 Bec Jeremie, Observatoire de la, Cote d'Azur; 21.05.2002 - 31.05.2002, KGV;
 Benamour Moulay-Tahar, Université Claude Bernard, Institut G. Desargues, Bat.101; 17.09.2002 - 23.09.2002, RGK;
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 Bhattacharya Siddhartha, Tata Institute; 01.01.2002 - 17.05.2002, SCH;
 Biferale Luca, University of Rome, Dept. of Physics; 11.06.2002 - 28.06.2002, KGV;
 Bilu Yuri, Université Bordeaux 1; 18.04.2002 - 05.05.2002, TIG;
 Birkner Matthias, Universität Frankfurt, Fachbereich Mathematik; 16.12.2002 - 19.12.2002, BBB;
 Blachowska Dorota, University of Lodz, Faculty of Mathematics; 12.08.2002 - 17.08.2002, RGK;
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Buchholz Detlev, Universität Göttingen, Institut für Theoretische Physik II; 29.07.2002 - 12.08.2002, FWY;

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Schmeling Jörg, Lunds Universität, LTH; 06.07.2002 - 19.07.2002, TIG;
Schlickewei Hans Peter, Philipps-Universität, Fachbereich Mathematik und Informatik ; 26.02.2002 - 24.03.2002, TIG; 19.04.2002 - 22.04.2002, TIG;
Schmüdgen Konrad, Universität Leipzig, Mathematisches Institut; 17.09.2002 - 30.09.2002, MTK;
Schrader Robert, Freie Universität Berlin, Institut für Theoretische Physik; 29.07.2002 - 02.08.2002, LIEB;
Schroer Bert, CBPF Rio de Janeiro; 28.06.2002 - 12.07.2002, YNG;
Schücker Thomas, Centre de Physique Théorique ; 11.11.2002 - 23.11.2002, MTK;
Schwarz Albert, University of California at Davis; 07.09.2002 - 25.09.2002, MTK;
Schweitzer Paul A., Pontificia Universidade Católica do Rio de Janeiro, Depto. de Matematica; 29.07.2002 - 10.08.2002, RGK;
Seiler Erhard, Max-Planck-Institut für Physik; 28.07.2002 - 31.07.2002, LIEB;
Seiler Ruedi, Technische Universität Berlin; 29.07.2002 - 03.08.2002, LIEB;
Seo Byoung Ki, Korea Advanced Institute of Science and Technology, Department of Mathematics; 12.07.2002 - 31.07.2002, SCH;
Ševera Pavol, Comenius University, Faculty of Mathematics and Physics, Department of Theoretical Physics; 22.10.2002 - 31.10.2002, MTK;
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Shnirelman Alexander, Tel Aviv University, School of Mathematics; 22.06.2002 - 30.06.2002, KGV;
Sidorov Nikita, University of Manchester , UMIST, Institute of Science and Technology; 16.06.2002 - 06.07.2002, TIG;

Sigal Israel Michael, University of Toronto, Dept. of Mathematics; 29.07.2002 - 31.07.2002, LIEB;
 Sinai Yakov, Laudon Institute, of Theoretical Physics; 26.05.2002 - 03.06.2002, KGV; 30.07.2002 - 05.08.2002, LIEB;
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 Smorodinsky Meir, Tel Aviv University; 19.06.2002 - 01.07.2002, KGV;
 Sobolevskiy Andrey, Moscow State University, Physics Department, Quantum Statistics and Field Theory Division; 24.05.2002 - 07.06.2002, KGV;
 Solomyak Boris, University of Washington, Department of Mathematics; 26.06.2002 - 30.06.2002, TIG; 01.07.2002 - 08.07.2002, TIG;
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 Tilouine Jacques, Université Paris 13, Institut Galilée; 28.01.2002 - 02.02.2002, JS;
 Todorov Ivan, Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy; 01.03.2002 - 16.04.2002, SF; 26.08.2002 - 15.09.2002, MTK; 04.11.2002 - 31.12.2002, SF;
 Tria Francesca, Università "Federico II", Dipartimento di Scienze Fisiche; 16.12.2002 - 22.12.2002, BBB;
 Tsuboi Takashi, University of Tokyo; 31.07.2002 - 10.08.2002, RGK;
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 Unruh William G., University of British Columbia, Department of Physics; 16.07.2002 - 15.08.2002, FWY;
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 Vershik Anatoly, Mathematical Institute of Russian Academy of Sciences; 15.10.2002 - 25.12.2002, SF;
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 Vincenzi Dario, Observatoire de la Cote d'Azur ; 01.07.2002 - 10.07.2002, KGV;
 Vogel Thomas, Universität München, Mathematisches Institut; 21.10.2002 - 26.10.2002, RGK;
 Vogt Elmar, Freie Universität Berlin, 2. Math. Institut; 31.07.2002 - 10.08.2002, RGK;
 Vulpiani Angelo, University of Rome, Department of Physics; 01.07.2002 - 13.07.2002, KGV;
 Wagner Günter, Yale University, Department of Ecology and Evolutionary Biology ; 10.12.2002 - 18.12.2002, BBB;
 Wakolbinger Anton, Universität Frankfurt, FB Mathematik; 16.12.2002 - 24.12.2002, BBB;
 Walczak Pawel, University of Lodz, Faculty of Mathematics ; 22.07.2002 - 17.08.2002, RGK;
 Wald Robert, University of Chicago, Enrico Fermi Institute; 04.07.2002 - 23.08.2002, FWY;
 Waldram Daniel, Queen Mary University of London; 18.11.2002 - 22.11.2002, RGK;
 Waldschmidt Michel, Université M. Curie, Institut de Mathématiques; 07.07.2002 - 20.07.2002, TIG;
 Warzel Simone, Universität Erlangen, Institut für Theoretische Physik; 28.07.2002 - 02.08.2002, LIEB;
 Wehr Jan, University of Arizona; 27.05.2002 - 20.06.2002, KGV;
 Weinan E, Princeton University; 29.05.2002 - 04.06.2002, KGV;
 Weinzierl Stefan, Dipartimento di fisica; 26.08.2002 - 05.09.2002, MTK;
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 Wiegmann Paul B., University of Chicago, Dept. of Physics; 28.10.2002 - 07.11.2002, MTK;
 Wohlgenannt Michael, Universität München, Institut für Theoretische Physik; 03.11.2002 - 07.11.2002, MTK;

Wolak Robert, Uniwersytet Jagiellonski, Instytut Matematyka; 04.08.2002 - 18.08.2002, RGK; 08.10.2002 - 23.10.2002, RGK;

Wulkenhaar Raimar, Max-Planck-Institute for Mathematics in the Sciences; 16.09.2002 - 27.09.2002, MTK;

Wüstholtz Gisbert, ETH Zürich; 25.02.2002 - 05.05.2002, TIG; 26.08.2002 - 15.09.2002, SCH;

Yajima Kenji, University of Tokyo, Department of Mathematical Sciences; 27.07.2002 - 03.08.2002, LIEB;

Yakir Benjamin, The Hebrew University at Jerusalem, Department of Statistics ; 29.01.2002 - 06.02.2002, BBB;

Yau Horng-Tzer, New York University, Courant Institute; 28.07.2002 - 01.08.2002, LIEB;

Yokura Shoji, University of Kagoshima, Faculty of Science, Dept. of Mathematics and Computer Science; 24.07.2002 - 27.08.2002, MI;

Yoshida Minoru W., The University of Electro.-Commun. Systems Engineering; 29.07.2002 - 01.08.2002, LIEB;

Zambrini Jean-Claude, GFM (Group of Math. Physics); 28.07.2002 - 01.08.2002, LIEB;

Zakharov Vladimir, University of Arizona , Landau Institute for Theoretical Physics; 01.07.2002 - 16.07.2002, KGV;

Zarembo Konstantin, Department of Theor. Physics, Uppsala University; 31.10.2002 - 08.11.2002, MTK;

Zahle Iljana, Universität Erlangen; 16.12.2002 - 20.12.2002, BBB;

Zeidler Eberhard, Max-Planck-Institut for Mathematics, in the Sciences; 28.07.2002 - 02.08.2002, LIEB;

Zenk Heribert, Universität Wien, Institut für Theoretische Physik; 28.07.2002 - 02.08.2002, LIEB;

Zhang Ruibin, University of Sydney, School of Mathematics and Statistics; 28.10.2002 - 03.11.2002, MTK;

Activities in electronic information and communication

by Peter W. Michor

Report on the Activities of the Committee on Electronic Information and Communication (CEIC) of the International Mathematical Union in the year 2002.

Fifth Meeting of the CEIC. The Fifth Meeting of the CEIC was held at the Morris J. Wosk Centre for Dialogue, Simon Fraser University, Vancouver, February 15–17, 2002. A report on the meeting is included in the report on the 4 year term of the CEIC in the IMU-Bulletin 48 (June 2002), pages 70–80.

Membership and Participation Peter Michor (Austria), Jonathan Borwein (Canada), John Ewing (USA), Martin Grötschel (Germany), Wilfrid Hodges (UK), David Morrison (USA), Kapil Paranjape (India), Alf van der Poorten (Australia), Alexei Zhizhchenko (Russia). By invitation: Laurent Guillope (France), Patrick Ion (USA), Alejandro Joffre (Chile), Greg Kuperberg (USA). Did not attend: Jonas Gomes (Brazil), Qing Zhou (China). A number of Canadian visitors attended all but the last session of the meeting.

The CEIC met on Friday, February 15 (commencing at 10:00) and through Sunday, February 17. Saturday, February 16, consisted of a CEIC Workshop “Managing digital information in mathematics: From journals to the grey literature”.

The meeting concluded with a frighteningly expensive dinner, on the evening of February 17, at which members ate heartily and plotted the future of the Committee.

General discussion of the future of CEIC. One of the main aims of the next CEIC should be foster further international cooperation between the main international players: arXiv, Math-Net, MPRESS, EMIS, Mathematical Societies active in publishing. In particular CEIC should be a meeting ground for the most active persons in non-commercial (and commercial) electronic publishing, including and concentrating on preprint servers.

Recommendations. In accordance with its remit, CEIC spent a substantial part of the meeting discussing a list of recommendations on best practice in the field of electronic information and communications and immediately related issues. Recommendations will have reached final draft form for the next meeting of the EC, for its eventual endorsement.

- The issue of versioning of archived articles.
- Archiving articles and on otherwise making them available on the web.
- Bundling and related behavior of journal publishers.
- Recommendations specific to developing countries

The World Digital Mathematical Library. Some half dozen centres in various countries now have projects to scan the existing mathematical literature thus making it available in digital form (retrodigitisation). This current development is of great importance for mathematics and warrants the attention of the IMU. The value of these efforts will be much enhanced if they are truly international and if there is some overall co-ordination (inter alia to minimise duplication and to identify best practice) and facilitation. *CEIC urges the IMU to accept a*

central role in the co-ordination and facilitation of the World Digital Mathematical Library project. Presuming that the issue is deemed within the terms of its mandate, CEIC offers the expertise and experience of its members to act on behalf of the IMU.

Mathematical Copyright

The Committee noted that the IMU/CEIC statement prepared by Wilfrid Hodges, and links pointing to it, is almost the only web item on mathematical copyright and general copyright guidelines. Nonetheless, there are related matters of interest to mathematicians on the web. It was therefore agreed that the CEIC website be enhanced and updated by preparing brief summaries of and links to such items. Alfvdp agreed to take eventual responsibility for these matters.

Access for third world countries Principal centres have problems similar to those experienced in the west. More generally, however, infrastructural deficiencies are commonplace. These may include basic connectivity problems because of an unreliable telephone system, inadequate capacity servers, low local bandwidth (so that North American and European sites may be more readily available than are local mirrors); thus archival access is problematic. It is typical for many scientists to have access only to the one machine for their common use. Certainly, anecdotal remarks tell of scientists obtaining more convenient access from internet cafes than from departmental machines. Naturally, there is real conflict between the desire and need to use common computers for apparently ‘non-mathematical’ activity (e-mail and web access) and their use as a research technical tool.

Math-Net Martin Grötschel reported on recent developments which are to culminate with a press release to be issued after the EC meeting of April 12 announcing that the Math-Net pagemaker for homepages of Institutes, Departments, and Centres is now available.

The CEIC agreed that it is now appropriate to proceed with work on a similar Math-Net personal homepage and asked each committee member to oversee the making of several institutional homepages before the announcement in April.

Final CEIC closed working session

Acting on an e-mailed request of David Mumford, the CEIC rediscussed the Budapest Open Access Initiative (BOAI) (<http://www.soros.org/openaccess>) noting that parts of the BOAI of course coincide with advice and recommendations of the CEIC, but more particularly remarking that its more impassioned demands are less than totally realistic. Jon Borwein was deputed by the Committee briefly to detail these issues to David Mumford.

In reconsidering its recommendation that mathematicians be encouraged to scan their old (pre- \TeX) papers, and to place them on the web, the CEIC agreed to collect a variety of personal descriptions and discussions of how such a project had been completed and to make stories available on the CEIC pages.

It was reported that agreements had been made to have the ICM proceedings available as arXiv overlay.

Presentation to the General Assembly. The general assembly of the IMU (Shanghai, August 17 and 18, 2002) received a report by Martin Grötschel, IMU EC representative, Peter Michor, Chair of the CEIC, and Alf van der Poorten, on the activities of the CEIC during the past four years.

The presentation included a brief review of mathematics on the Web, an introduction to Math-Net and the importance of Math-Net Pages for mathematical institutes and departments, a preview of standardized personal pages for mathematical researchers, an outline of the “Best Current Practices Recommendations” on electronic publishing including a review of mathematical preprint servers, a call to all mathematicians to make their publications electronically available, an explanation of CEIC’s copyright recommendations, and an outline of plans for a Digital Mathematics Library.

CEIC Recommendations. The Committee prepared a booklet collecting CEIC’s current recommendations on various aspects of electronic information and communication. Those recommendations had been drafted by CEIC members and were finalized in open discussions during CEIC’s 1998–2002 term. They were variously endorsed by the IMU Executive Committee and by the Shanghai General Assembly.

The booklet was distributed at the GA in printed form. It is electronically available at CEIC’s web site http://www.ceic.math.ca/filemgmt_data/files/recommendations.pdf

Future of the CEIC. The CEIC was reviewed by the IMU EC at its meeting preceding the GA. The EC determined to re-establish the CEIC for a second term with revised terms of reference (included below).

The following resolution (Resolution 6) summarizing the work of CEIC was adopted by the General Assembly:

The General Assembly of the IMU endorses the "Best Practices" document of its Committee on Electronic Information and Communication (CEIC), also endorsed by the IMU Executive Committee at its April 13, 2002, meeting. In particular the Assembly endorses the provisions designed to ensure access by mathematicians of the developing world to current mathematical literature: the posting of the articles on personal homepages and servers and the practice now beginning with several publishers of making journal articles in electronic form freely accessible five years after they have been published, or even sooner. An important part of making mathematical literature available is coming to agreement on common standards for digitization. The Assembly commends the CEIC for its work on this matter and urges further efforts in this direction.

CEIC Activity at the ICM, Beijing. Members of the CEIC held an informal lunch time meeting to discuss further plans of the Committee.

On Monday, August 26, CEIC organized an afternoon special session: New Aspects of Electronic Publishing.

The following talks were given: Jonathan Borwein: What is the CEIC? Roland Schwaenzl: Where should you put your papers? Wilfrid Hodges: Should we give away our research? Martin Grötschel: Can we make information more accessible? John Ewing: How long should publishers own scholarship? Alf van der Poorten: Is refereeing necessary? Panel discussion: What are best practices and why should you care?

Satellite Meeting. Members of the CEIC participated in the satellite conference "Electronic Information and Communication in Mathematics" at Tsinghua University in Beijing (August 29–31, 2002), and gave the following talks:

Peter Michor (keynote): Doing Mathematics in the years 1949, 1973, 2003, 2039. Jonathan Borwein: The next four years. Wilfrid Hodges: Copyright in mathematical work. Alf van der Poorten: The costs and benefits of refereeing. Alexei B. Zhizhchenko: Electronic information system in mathematics in Russia and participation of Russia in the Mathnet project. John Ewing: Predicting the future.

The next meeting of CEIC is scheduled to be held in Berlin, May 24-25, 2003.

New terms of reference. At its 70th session on August 16, 2002, in Shanghai the IMU Executive Committee has reviewed the activities of its "Committee on Electronic Information and Communication" (CEIC) and decided to re-establish CEIC for a second term with the following revised terms of reference:

a) The CEIC is a standing committee of the Executive Committee (EC) of the IMU, reviewed every four years by the EC at its meeting preceding that of the GA. Members are appointed for four year terms by procedures similar to those for IMU Commissions. The EC appoints one of its members to serve on the CEIC.

b) The CEIC may meet as necessary in each four year period to review the development of Electronic Information and Communication as it impacts the international mathematical community, and is asked to submit an annual report to the EC.

c) The CEIC may organize or sponsor international meetings or forums to bring together representatives of all interested parties, including societies, publishers, libraries, researchers, and sister disciplines. It may publish, electronically or on paper, and otherwise disseminate proceedings, reviews of recent developments, and technical surveys for the use of the mathematical community.

d) The CEIC may suggest international standards ('best practice recommendations') on issues related to electronic communication. Such recommendations should be reviewed by the EC and, if approved, may be published and promoted in the name of the IMU.

e) The CEIC is expected to continue its previous efforts such as the promotion and organization of Math-Net and related activities that make mathematics related material electronically

available. In carrying out its activities, CEIC is asked to continue soliciting the views of the mathematical community through the CEIC and the Math-Net homepages.

The CEIC is asked to address, in its second 4-year term, the following issues with special emphasis.

f) The CEIC is requested to enhance its advisory role with the aim

- to make the issues involved generally understood,
- to define the relevant needs of our discipline clearly,
- to shape the role the mathematical community needs to play, and
- to guide the practice of scholarly communication and publication.

g) The CEIC is asked to take an active part in any development of a Digital Mathematics Library, to further address copyright and archiving issues, journal licensing models, and cost models for journal production and acquisition.

h) The CEIC is requested to draft a proposal, to be decided upon by the EC in 2006, concerning its future status. The proposal should include issues such as CEIC's institutionalization, membership, long term financing, and sustainability of the various current CEIC efforts and activities.

The composition of CEIC for the next period is as follows:

Pierre Berard,
Jonathan Borwein, chair,
John Ewing,
Martin Grötschel, IMU-EC representative,
Alejandro Joffre,
Peter Michor,
David Morrison,
Alf van der Poorten.

The following two persons are attached to CEIC with special emphasis on the further development of the World Digital Mathematical Library:

Rolf Jeltsch,
David Mumford.