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

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A-1090 Vienna, Austria

# Scientific Report for 2004

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# A preface by the President

In spite of a difficult and uncertain financial climate the twelfth year of operation of the Erwin Schrödinger International Institute for Mathematical Physics (ESI) saw some very positive developments. Perhaps the most important of these was the start of the *Junior Research Fellows Program* in February 2004. This program is funded by the Ministry of Science (BMBWK) with €150.000 per year for an initial period of three years, and has the purpose of supporting Post-Docs and PhD-students to enable them to participate in the scientific activities of the Institute, to strengthen and deepen their contacts with the Austrian and international research communities, and to work with individual visitors and Austrian scientists. Fellowships are awarded on a competitive basis for periods of 2 – 6 months and are funded on a scale roughly comparable with junior FWF Research positions.

Although the program started only in 2004, both the number and the quality of the applicants for that year exceeded all expectations. About 70% of all applicants were of worthy of support by international standards, but the available funding only allowed us to offer fellowships to fewer than 25% of the candidates. The total number of ESI Junior Research Fellows in 2004 was 19.

The presence of the Junior Research Fellows had a very noticeable impact on the scientific atmosphere at the Institute through a series of *Junior Research Fellows Seminars*, in which they were encouraged to present their research, and through lively discussions and interaction with other post-docs and visitors at the Institute.

The Junior Research Fellows Program also interacted very well with the *Senior Research Fellows Program* of the Institute, which had started in 2003 in line with our long-term policy of vertical integration of research and scientific education at highest international levels. The latter program is funded by the Ministry of Science and the University of Vienna (with annual contributions of €94.000 and €22.000, respectively) and has the purpose of inviting senior scientists for extended periods of time to offer advanced lecture courses and longer-term scientific interaction with graduate students, post-docs and the local scientific community. This program is organized by Joachim Schwermer and is described in detail on p. 25ff.

The development of these two Research Fellows Programs made it necessary to expand the Institute by renting additional space along the corridor providing access to the ESI (the decision to do so had already been taken in 2003) and to adapt a large lecture hall and several rooms along this corridor. The necessary building work is now essentially complete, apart from a few finishing touches, and has helped to provide a number of new offices for Junior and Senior Research Fellows, program organizers and longer term visitors.

In spite of these positive developments I have to end this preface on a sombre note. The basic funding of the ESI has not seen any significant increase since 1993, when the Institute was founded, and has been cut by 14.4% since 2003. Combined with erosion by inflation over this period this amounts to an effective reduction of the basic funding by more than 40% since 1993. This has a serious impact on our core research programs on which the success of the Junior and Senior Research Fellows Programs rests. In order to counteract this development an increase in the Institute's basic funding for the next years becomes an absolute priority.

Klaus Schmidt March 11, 2005

# General remarks

### Management of the Institute

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Administration: Maria Windhager, Isabella Miedl, Ursula Sagmeister
Computers: Andreas Čap, Gerald Teschl, Hermann Schichl

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**Budget and visitors:** The budget of ESI for 2004 was € 762.880,– from the Austrian Federal Ministry for Education, Science and Culture (incl. € 94.000,– for the Senior Research Fellows Program), € 22.000,– from the University of Vienna for the Senior Research Fellows Program and € 5.000,– from various external sources. € 443.982,– were spent on scientific activities and € 463.621,– on administration and infrastructure. Visitors and Post-Docs supported from other sources contributed the equivalent of almost a further € 400.000,–.
The number of scientists visiting the Erwin Schrödinger Institute in 2004 was 424, and the number of preprints was 132.

# Programs in 2004

## Geometric and analytic problems related to Cartan connections

**Organizers:** T. Branson, A. Cap, and J. Slovák

**Budget:** ESI €57.375,–

**Dates:** January 2 - April 20, 2004

**Preprints contributed:** [1458], [1466], [1475], [1477], [1478], [1480], [1483], [1484], [1486], [1492], [1496], [1513], [1538], [1563], [1567]

### Report on the program

This program took place in the first months of 2004. It was planned from the beginning as being rather spread out with not too many visitors at a time, and without workshops or similar activities. The program brought together a total of 49 visitors, almost all of them mathematicians (see the list at the end of this report). We would like to point out that we had several long term visitors, in particular several members of the Prague group. These included Ph.D. students and recent post-docs, which partly were financed from other sources. Due to several unexpected cancellations in the last period of the program we did not use up our budget.
The visitors delivered a total of 34 lectures. The complete list of lectures (most of them with abstracts) can be found at
http://www.mat.univie.ac.at/∼cap/esiprog/lectures.html.

The aim of the program was twofold: About half of the participants met more often in activities on conformal and CR geometry and generalizations. The program came between two rather condensed activities in that direction (in summer 2003 at the AIM in Palo Alto and in summer 2004 at BIRS in Canada). For these people, the program at the ESI was a great opportunity to continue existing collaborations and work on joint projects without time–pressure. The general atmosphere of the ESI and the structure of the program served this purpose very well. Examples for results of such collaborations are preprints [1458] (with authors from Europe, the USA, Australia and New Zealand) and [1484] (with authors from the USA and Japan).

The second main aim of the program was to bring together people who work on structures admitting Cartan connections from different points of view (examples are described below). This led to a considerable amount of cross fertilization. On the one hand, the general point of view of Cartan connections has some unexpected implications on specific examples. On the other hand, detailed information on specific examples is always very helpful for those working on the general theory. In this direction, the program made it possible to establish several new contacts as well as intensify existing contacts. While most of these new contacts have not yet lead to preprints or articles (an exception being [1486]) we consider them as extremely valuable.

The main scientific topics of the program were the following:
**1. Parabolic geometries:** These are geometric structures which admit a canonical Cartan connection with homogeneous model the quotient of a semisimple group by a parabolic subgroup. Both the general theory of these structures and specific examples of these geometries, in particular conformal structures and CR structures were studied intensively during the program.

A particularly active area in this direction is the study of Poincaré metrics and ambient metrics. These relate conformal structures, CR structures, and quaternionic contact structures

(which all are parabolic geometries) to conformally compact Einstein, Kähler Einstein, and quaternionic Kähler Einstein manifolds. Here the program was very helpful in establishing contacts between people working in parabolic geometries and the conformal and CR cases with the group of Olivier Biquard, who is the top expert for the quaternion Kähler case.

During the last years, conformal geometry and Poincaré metrics have also become popular in analysis. This is mainly due to unexpected relations with scattering theory and to the introduction of $Q$–curvature, which leads to higher dimensional analogues of the Gauss curvature prescription problem. During the program, we had a visit by a small but very strong group working in that direction (see preprint [1513]). Unfortunately, the visit of this group was in a period with little other activity, so there was less interaction between analysts and geometers than we originally had hoped for.

Some important connections were made to spin geometry, as it is studied by the group around Helga Baum for example. By applying the theory of tractor bundles, which is part of the general machinery for parabolic geometries, spin geometers have recently been able to settle some outstanding questions on, for example, the structure of Lorentzian conformal manifolds admitting a Killing spinor. This is an example of cross-fertilization of fields for which the ESI program was a major backdrop.

**2. Relations to symmetric spaces and representation theory:** The homogeneous models for parabolic geometries are generalized flag manifolds. Natural vector bundles give rise to homogeneous vector bundles on the homogeneous model. Restricting to irreducible representations of the parabolic, the spaces of smooth sections of these bundles are principal series representations of the semisimple group. Hence natural differential operators, whose study is of central importance in the theory of parabolic geometries, in particular give rise to special intertwining operators between principal series representations. Conversely, more general intertwining operators, say pseudo–differential ones, are natural candidates for extension to natural operators for parabolic geometries. Moreover, invariant differential operators often show up in extremal cases for Sobolev embedding theorems and their generalizations.

At the end of the borderline Sobolev inequality series in the conformal case is an exponential class inequality, carrying the names (in different contexts) Adams, Beckner, Moser, and Trudinger. The corresponding thing in the CR case is not yet well understood, and there was discussion of this, for example by Michael Cowling and Bent Ørsted. The class of groups for which such a phenomenon exists is related to the property of accessibility of the trivial representation through the complementary series, a part of the principal series. The ESI program was a unique opportunity to explore such connections between Lie theory and 'hard' analysis. Much remains to be done in this direction in the coming years.

Finally, for real rank one groups, the generalized flag manifold corresponding to the unique non–trivial parabolic can be realized as the boundary of a symmetric space of non–compact type. (This also provides the basic example of a Poincaré metric as discussed in 1.) This leads to Poisson transforms relating geometric objects on the boundary and in the interior. A better understanding of the geometry of the boundary can lead to new information in the interior. For example, it seems that ideas from parabolic geometries can play an important role in Pierre Julg's work on the Baum–Connes conjecture for discrete subgroups of $Sp(n,1)$.

**3. Other examples of Cartan geometries:** Associating to some geometric structure a canonical Cartan connection is a big step towards understanding of the structures. There are a number of general tools for the construction of such a connection available, for example Cartan's method of equivalence and various prolongation procedures. Applying these tools in concrete situations

however is not at all straightforward. The specific situation has to be analyzed carefully and often involved computations have to be carried out.

The participants of the program successfully applied such tools for example to sub–Riemannian structures, certain types of differential equations, and generalizations of path geometries.

**4. Relations to other special geometries:** Some of the concepts and results on conformal structures and more general parabolic geometries can be applied to other geometries. In particular this concerns special Riemannian structures, for example Sasakian structures, KT, and HKT structures (Kähler with torsion respectively Hyperkähler with torsion). Similarly, one can try to extend ideas from hypersurface type CR structures to CR structures of higher codimension, etc. A particularly interesting example of such an application can be found in preprint [1475]. This uses ideas from the theory of parabolic contact structures to obtain a complete local understanding of special symplectic connections. In particular, all the "difficult" exotic holonomies are obtained from special symplectic connections and therefore covered by the result.

**Invited scientists:** Pedro Albin, Dmitri Alekseevsky, Toby Bailey, Maria Laura Barberis, Helga Baum, Olivier Biquard, Thomas Branson, Jarolim Bureš, David Calderbank, Alice Sum-Yung Chang, Michael Cowling, Boris Doubrov, David Duchemin, Michael Eastwood, Anna Fino, Daniel Jeremy Forrest Fox, Krzysztof Galicki, Rod A. Gover, Robin Graham, Matthew Gursky, Oussama Hijazi, Kengo Hirachi, Doojin Hong, Pierre Julg, Jerzy Konderak, Lukas Krump, Svatopluk Krysl, Felipe Leitner, Tohru Morimoto, Paul-Andi Nagy, Pawel Nurowski, Bent Orsted, Gerd Schmalz, Lorenz Schwachhöfer, Uwe Semmelmann, Josef Silhan, Jan Slovák, Dalibor Smid, Petr Somberg, Vladimir Souček, Robert Stanton, Jacek Tafel, William Ugalde, Alfredo Villanueva, Gregor Weingart, Keizo Yamaguchi, Paul Yang, Vojtěch Zádník, Dmitri Zaitsev

## String Theory in Curved Backgrounds and Boundary Conformal Field Theory

**Organizers:** H. Grosse, A. Recknagel, and V. Schomerus

**Budget:** ESI €61.200,–

**Dates:** March 1 - June 30, 2004

**Preprints contributed:** [1491], [1504], [1505], [1514], [1517], [1518], [1519], [1532], [1534], [1535], [1549], [1557], [1568], [1569], [1570], [1571], [1572], [1573], [1574], [1575], [1576], [1577], [1578], [1579], [1580], [1583], [1584], [1585], [1586], [1589], [1590], [1591], [1592], [1594], [1595], [1596], [1597], [1599], [1604], [1605]

### Report on the program

The programme had two main hubs of activity around workshops on 'Mathematical and physical aspects of branes in Calabi-Yau spaces', from April 29 to May 11, and on 'String theory on non-compact and time-dependent backgrounds', from June 7 to 18. On the whole, more than fifty participants were visiting the programme, most of them from Europe.

Our main aim during the first of the workshops was bringing together mathematicians working on or near algebraic geometry and physicists interested in string compacitifications on Calabi-Yau spaces. A number of lectures series by Wendland, Kapustin, Szendroi and Scheidegger covered some of the field's central recent developments. Each of them started out in a relatively introductory fashion but reached the forefront of research. The speakers all made

great efforts to deliver good lectures, and judging from comments made by participants (experts and new-comers alike), they succeeded splendidly with their talks. In addition to these lectures series, one or two research seminars per day complemented the scientific program of the first workshop. With no more than three talks per day (26 seminars/lectures in two weeks), there remained ample time for intense interaction among the participants. Let us add that the talks were also attended by quite a number of researchers from Vienna, including PhD students.

The second workshop dealt with string theory on non-compact spaces. During the first week, the talks mainly focused on themes relevant for the description of strings in $AdS_3$. Two lecture series by Teschner and Berkovits provided an introduction to the status of the field. They were accompanied by lecture series of Sorba and MacKay treating some of technology (Lie-superalgebras and Yangians) that will be relevant in future developments. During the second week, lectures by Berkooz and Fendley as well as a large number of seminars treated mostly time dependent string backgrounds and the closely related studies of renormalization group flows in 2-dimensional conformal field theories. While the lectures and seminars of the second workshop were certainly more technical, the event visibly triggered very intense discussions among the participants, even late into the nights. As far as we know, several projects have either been initiated or have received crucial new input during these two weeks.

In between the two workshops, there were in particular a number of talks on non-commutative geometry, dealing with its applications in string theory and quantum field theory as well as with intrinsic mathematical problems. In addition, a few collaborations used the quieter atmosphere at ESI to advance their research projects. One of the organizers (V.S.) gave a series of introductory lectures into boundary Liouville theory, partially so as to provide the local PhD students with the necessary background knowledge to be able to follow the second workshop.

We would like to thank the ESI board for giving us the opportunity to organize this programme. Many thanks are due to the ESI secretaries Maria Windhager, Isabella Miedl and Ursula Sagmeister who were always reliable, efficient and incredibly helpful; indeed, we never had to deal with any 'profane details' after the initial phase of tentative invitations and negotiations with prospective participants. Judging in particular from the feedback of participants, we believe that this programme has been remarkably successful. In fact, many participants have expressed their strong interest in a short followup meeting to discuss recent progress and to strengthen new collaborations.

**Invited scientists:** Oleg Andreev, Paolo Aschieri, Gergely Berczi, Micha Berkooz, Nathan Berkovits, Daniel Blakeley, P.G. Bouwknegt, Maja Buric, Andrea Cappelli, Alan L. Carey, Bianca Letizia Cerchiai, Ben Craps, Giuseppe D'Appollonio, Patrick Dorey, Hakon Enger, Paul Fendley, Alice Fialowski, José M. Figueroa-O'Farrill, Anamaria Font, Patrick Foulon, Stefan Fredenhagen, Matthias Gaberdiel, Gerhard Götz, Kevin Graham, Branislav Jurčo, Anton Kapustin, Peter Kaste, Neil Lambert, Giovanni Landi, Wolfgang Lerche, Niall MacKay, John Madore, Anatol Odzijewicz, Jacek Pawelczyk, Paul A. Pearce, Thomas Quella, Andreas Recknagel, Soo-Jong Rey, Sylvain Ribault, Daniel Roggenkamp, Ingo Runkel, Rolf Schimmrigk, Volker Schomerus, Peter Schupp, Adam Schwimmers, Paul Sorba, Rafal Roman Suszek, Harold Steinacker, Balázs Szendroi, Andras Szenes, Jörg Teschner, Stefan Theisen, Mathai Varghese, Gerard Watts, Katrin Wendland, Julius Wess, Peter West, Raimar Wulkenhaar.

## Tensor categories in Mathematics and Physics

**Organizers:** J. Fuchs, Y.Z. Huang, A. Kirillov, M. Kreuzer, J. Lepowsky and C. Schweigert

**Budget:** ESI €38.250,–, external sources $ 20.000,– (National Science Foundation, USA) and €1.500,– (Vienna Convention Bureau)

**Dates:** May 31 - July 9, 2004

**Preprints contributed:** [1547], [1545], [1544], [1543], [1502], [1499], [1491], [1548], [1565], [1603], [1606]

**Report on the program**

It is already known for quite a while that the theory of tensor categories provides a unifying language for various parts of mathematics and applications of mathematics, in particular in physics. However, in some recent developments this insight has been particularly fruitful.

It was the aim of the program to bring together experts from several different areas of mathematics as well as mathematical physics who are involved in these developments. Correspondingly the area covered by the program was very broad, including e.g. subjects from the theory of vertex algebras, nets of von Neumann algebras, operads, infinite-dimensional Lie algebras, weak Hopf algebras and quantum groupoids, Galois theory, conformal field theory and topological field theory. Each of these fields was represented by leading experts.

The participants benefitted a lot from communicating results between the various disciplines and from the attempt to understand them in the unifying language of tensor categories. These attempts gave rise to many questions during and after the talks, and, maybe even more importantly, also resulted in numerous and lively private discussions among the participants. In the schedule, this was facilitated by allocating 90 minutes to many of the lectures and by allowing for sufficiently long breaks between the presentations.

It is helpful to compare the situation at the time when the idea to organize a program on this subject was born to the situation today.

- In many of the fields named above made there has been important, sometimes even spectacular, progress. Much of this progress was presented at the program. In a few cases the results were actually presented at the program for the first time, and more frequently it was at least for the first time to an audience of such a varied background. As examples, we mention Huang's proof of the Verlinde conjecture in the context of vertex algebras, Masbaum's work on integral structures in topological quantum field theories, and Ocneanu's ideas on atlases of quantum groups.
- In surprisingly many cases, the progress involved the transfer of ideas and / or techniques from other fields. Tensor categories have proven to provide a most valuable tool in this process. An important contribution of this ESI program with long term impact is, in our opinion, the fact that it has further promoted tensor categories as a unifying language. In fact, this ESI program has been the so far most prominent meeting point of two communities working on the structure of chiral conformal field theory, the vertex algebra-community and $C^*$-algebraists.
- Other scientific events will follow up the activity at ESI. For instance, in May 2005 there will be a conference on 'Lie Algebras, Vertex Operator Algebras and their Applications'[1] at North Carolina State University, and in July 2005 a conference on "Categories in Algebra, Geometry and Mathematical Physics"[2] will be held in Sydney. The organizers of the latter conference refer in their announcement to the 'recent explosion of applications [that show] a

[1] `http://www4.ncsu.edu/~misra/LieConf2005`
[2] `http://streetfest.maths.mq.edu.au`

clear tendency for category theory to become a universal language for algebra, geometry and mathematical physics.'

The program also had some training impact on young researchers. Local students and postdocs could benefit from a series of lectures one of the organizers (J.F.) gave as an ESI senior fellow; the last part of those lectures could serve as a direct preparation for some of the talks at the workshop. Two sessions with short communications offered a possibility to young participants to present aspects of their work.

Some of the highlights of the program were the following:

- Huang reported on a breakthrough in the proof of the Verlinde conjecture in the framework of vertex algebras. In this work, a certain (co-)finiteness condition plays a crucial role. This is also central to the work of Tsuchiya on fusion functors.
- Szlachányi gave a status report on his research program on quantum groupoids. It seems fair to say that quantum groupoids have by now been established as the appropriate generalization of Hopf algebras to situations in which only bi-module valued fiber functors exist. They also provide a convenient setting to describe "quantum subgroups".
- The latter have been central to Ocneanu's talk. He also provided ideas for identifying canonical bases for representations of quantum groups. In such bases, particular number theoretic aspects should become accessible. They play an important role in Masbaum's work on integral structures in TQFT as well.
- Another way to think about "quantum subgroups" is provided by module categories. Ostrik presented new applications of this notion to representations of quantum SL(2).
- E. Frenkel presented progress in his long-standing program of finding a Langlands correspondence for Kac-Moody algebras. Ideas from conformal field theory in general, and vertex algebras in particular, seem to become a more and more crucial input in this field.

Already this short list indicates the deep interrelations between many of the topics of the program.

Many of the other contributions were related to these highlights, too. For instance, in Szczesny's talk Frenkel's ideas were generalized to orbifold theories. Orbifolds are also crucial for monstrous moonshine; an extension of moonshine to the baby monster group was discussed by Höhn. Mason's talk related the theory of holomorphic orbifolds to group cohomology, while Müger's talk presented aspects of orbifold theory in the framework of conformal nets of $C^*$-algebras on $S^1$. (A review of the operator algebraic approach was given by Evans and by Kawahigashi.)

The modular group – being the mapping class group of the torus – and its representations played an important role in the talks of Gannon, Kedem, and Bantay. Its action is closely related to fusion rings, which summarize information about dimensions of spaces of intertwiners. Intertwiners of vertex algebras were discussed from various points of view in the contributions of Li, Milas, and Primc. While vertex algebras are, in some sense, local objects associated to complex curves, global algebraic structures associated to complex curves were the subject of the talks of Fialowski and Schlichenmaier.

Applications to physical models, in particular to gauge theories of higher spin fields and two-dimensional conformal field theory, were the subject of the talks of Fröhlich, Pfeiffer, and Runkel. The talks of Bruguières, Davydov, Kassel, Lyubashenko, and Pareigis presented new developments about tensor categories and their applications to topological field theory.

**Organization of the program:**
Originally, two periods of intense activities were planned. After reduction of the original budget, a large part of the activities was concentrated in a single two-week workshop, taking place 21 June – 2 July 2004. This workshop was prepared for local participants, in particular for students, by a series of lectures that one of us (J.F.) gave as an ESI senior fellow. Some of the participants were staying for an extended period before or after the workshop, in some cases on their own funding, in a few other cases in combination with some other ESI program.

We would like to express our gratitude for the efficiency and friendliness of the ESI staff. Working with them has been, at all stages of the program, a true pleasure.

**Invited scientists:** Marta Asaeda, Peter Bantay, Joseph Bernstein, Julius Borcea, Alain Bruguières, Corina Calinescu, Alexei Davydov, Chongying Dong, David Evans, Alice Fialowski, Jens Fjelstad, Edward Frenkel, Jürg Fröhlich, Jürgen Fuchs, Alexander Ganchev, Terry Gannon, Christopher Goff, Vincent Graziano, Gerald Höhn, Yi-Zhi Huang, Keith Hubbard, Alexander Ivanov, Christian Kassel, Yasuyuki Kawahigashi, Rinat Kedem, Alexander Kirillov Jr., Yau Kwan Kiu, Maximilian Kreuzer, Anna Lachowska, Jim Lepowsky, Haisheng Li, Volodymyr Lyubashenko, Gregor Masbaum, Geoff Mason, Arne Meurman,Antun Milas, Stephan Mohrdieck, Michael Müger, Kiyokazu Nagatomo, Adrian Ocneanu,Victor Ostrik, Bodo Pareigis, Hendryk Pfeiffer, Paulo Pinto, Mirko Primc, Alexander Retakh, Markus Rosellen, Ingo Runkel, Nobuya Sato, Karl-Georg Schlesinger, Martin Schlichenmaier, Christoph Schweigert, Eric Simring, Catharina Stroppel, Matthew Szczesny, Konstantin Styrkas, Kornél Szlachányi, Valerio Toledano Laredo, Akihiro Tsuchiya, Imre Tuba, Peter Vecsernyes, Robert Wendt, Pasquale Anthony Zito, Marco Zunino.

Of these 64 participants, 42 were supported at least in part by ESI, 15 US participants were supported by the NSF grant we got, and the remaining 7 came entirely on their own funds.

It is worth mentioning that a significant part of the funding was used to support young researchers as well as scientists from Eastern Europe.

## Singularity Formation in Nonlinear Evolution Equations

**Organizers:** P.C. Aichelburg, P. Bizoń

**Budget:** ESI € 34.425,–

**Dates:** July 7 - August 15, 2004

**Preprints contributed:** [1510], [1526], [1531], [1539], [1550], [1551]

### Report on the program

One of the main ideas of this workshop (July 1 to August 15,2004) was to stimulate interaction between people working on singularity formation in different areas of nonlinear evolution equations. We are very glad to report that this aim has been successfully accomplished. During the workshop, not only several collaborations have begun, but also substantial progress in specific problems was made. Below we list some of the research projects that originated during the workshop:

1. **Rate of blowup for the critical wave maps** (Sigal, Velazquez, Williams, Bizoń).

It is widely believed that in the critical case the blowup proceeds along the moduli space of a marginally stable stationary solution. Bizoń and Sigal worked out a perturbative computation

of the rate of blowup. Velazquez and Williams suggested to use the technique of matched asymptotics (very common for parabolic equations) to improve this computation. The problem is under investigation.

2. **Convergence towards a self-similar attractor** (Chmaj, Struwe, Bizoń).

For supercritical wave maps and Yang-Mills equations there exist stable self-similar solutions which are explicit examples of blowup. An important problem of asymptotic stability of these solutions is open. After learning about this problem, Struwe suggested to obtain the required estimates for energy by integrating the Morawetz type identities over the truncated light cone. Preliminary results seem promising.

3. **Critical behaviour in the gravitational collapse** (Aichelburg, Bizoń, Martin-Garcia, Tabor).

The problem of transition between continuous and discrete self-similarity in the critical gravitational collapse in the Einstein-sigma model has been actively discussed during the workshop. Martin-Garcia wrote a code to construct the discretely self-similar critical solution and Tabor, using his solver, provided the initial data for Garcia's code. The problem is now rather well understood and the results are being written up.

4. **Self-similar solutions of semilinear wave equations** $u_{tt} - \Delta u = u^p$ (Bizoń, Wasserman).

Under the assumption of self-similarity and spherical symmetry this problem reduces to a 3-dimensional dynamical system. Bizoń and Wasserman found a way to prove the existence of a countable family of solutions in the supercritical case $p = 7$. The proof is being written up. The corresponding proof for the subcritical case $p = 3$ is under investigation.

From the scientific perspective it would be highly desirable, and, we think, very much in the spirit of ESI, if the researchers involved in these projects could meet again to discuss progress and exchange ideas.

**Invited scientists:** Lars Andersson, Piotr Bizoń, Michail Dafermos, Marek Fila, Jörg Frauendiener, Markus Keel, Sergiu Klainerman, Philippe LeFloch, Jose M. Martin-Garcia, Vincent Moncrief, Matthias Mück, Alan Rendall, Hans Ringström, Israel Michael Sigal, Michael Struwe, Zbislaw Tabor, Juan Velazquez, Arthur Wasserman, J.F. Williams.

## Many-Body Quantum Theory

**Organizers:** M. Salmhofer, J. Yngvason

**Budget:** ESI € 57.375,–

**Dates:** September 1 - December 31, 2004

**Preprints contributed:** [1530], [1533],[1541], [1566]

### Report on the program

Many-body quantum theory is a large and well-developed field of theoretical physics, with many important applications in condensed matter physics, nuclear physics, and astrophysics. The fundamental problems are simple to formulate but hard to solve, and mathematical results have been obtained using a variety of methods, most of which require a rather specific setting.

The failure of approximations used previously in condensed matter physics, when dealing with the very interesting phenomena discovered in the study of new materials, has led to enormous activity in the field also from the theoretical physics point of view.

One of the main goals of the program at the ESI was to bring together the mathematically oriented and the more applied researchers in the field, to provide new problems for mathematical research on these topics and theoretical feedback to practitioners working in the field. The program, and in particular the workshops, served well in highlighting interesting and tractable mathematical problems and stimulating discussions about them. Progress in many–body theory takes time, due to the complications inherent in the subject, but a number of promising ideas came up and in the long term we expect interesting results from the activities in our program.

During the four–month research program the following three workshops took place:
*New mathematical problems in many–body theory* (September 6–11, 2004)
*Flow equation days* (October 20-22, 2004)
*Progress in mathematical many–body quantum theory* (December 1-4, 2004)
In the following we discuss topics that played a major role in the program.

**1. Spontaneous symmetry breaking and condensation phenomena**
These phenomena are the bread and butter of condensed matter physics, superconductivity, magnetism, and Bose–Einstein condensation being the best–known, but only a few, examples. They can be studied under many different conditions. The rigorous theory of Bose condensates in traps in the Gross–Piatevskii limit, based on variational methods, was described in the September and December workshops by Robert Seiringer and Jakob Yngvason, and formed part of the research in the program. Jakob Yngvason worked on the transition of a three-dimensional Bose gas to an effectively two-dimensional one in disc shaped traps. In the situation of a gas in the thermodynamic limit, there are only few results. Rigorous results on a quantum phase transition in a model of an optical lattice were presented by Robert Seiringer. J.-B. Bru described recent work on a variant of the Bogoliubov approximation which has the chance to describe superfluidity away from the dilute regime. Carlo di Castro discussed the role of Ward identities necessary for a treatment of Bose condensation in the infinite–volume system at nonzero densities. This problem is open mathematically and led to several discussions during the program. It can be reformulated as the proof of spontaneous symmetry breaking in an $O(2)$ nonlinear sigma model. This reformulation is interesting because the question of occurrence of superconductivity can also be formulated in terms of breaking of a $U(1)$ symmetry, albeit in a model with a much more complicated action. The only known proof of continuous symmetry breaking uses reflection positivity and does not apply to these situations.

**2. Fermion systems and fermionic methods**
The analysis of fermion systems in one and two dimensions has made significant progress since methods of constructive quantum field theory were brought to bear on these problems. The two–dimensional models, in particular the two–dimensional Hubbard model, are used as models for high–temperature superconductors. Among the topics discussed in the workshops were the analysis of two–dimensional fermions, in particular work by Afchain, Magnen, and Rivasseau, on the two–dimensional Hubbard model at half filling. During the program there were a number of discussions on the work of Pedra and Salmhofer about selfenergies and Fermi surface flows in two–dimensional fermion systems. The use of fermionic methods in the study of two–dimensional classical spin systems (using fermionic representations going back to McCoy and Wu) was discussed in the ESI junior fellow seminar by ESI junior fellow Giuliani, who finished this work (his PhD thesis work) at the ESI.

**3. Renormalization group methods**

Renormalization group (RG) methods are one of the tools that are presently being used extensively both by mathematical and theoretical physicists. RG methods are used in all of the proofs mentioned under item 2 above, and they are one of the routes followed in the attempt to prove spontaneous symmetry breaking, as discussed under item 1. On the applied side, approximate RG flows have recently become a versatile tool in the analysis of competing ordering tendencies and phases of low–dimensional correlated fermion systems. They also play a major role in the theory of quantum phase transitions and crossovers from classical to quantum critical dynamics. At present, one of the most interesting questions in the field is to control such flows in the broken–symmetry phase. Franz Wegner presented such flows for Hamiltonians in the September workshop; Salmhofer, Honerkamp, Metzner, and Lauscher, published a Wilsonian approach in ESI preprint 1533. The seminar by Wetterich on antiferromagnetism in the half–filled Hubbard model led to fruitful discussions about the flows away from half–filling, where the most interesting physical phenomena, such as pseudogaps, are expected to occur. During the *flow equation days*, a number of technical points concerning the comparison of different schemes were discussed as well.

A particularly important topic was the fulfilment of Ward identities in RG flows. Preserving Ward identities is of central importance for dealing with transport and symmetry–breaking phenomena correctly, as observed also in the above–mentioned studies on flows into symmetry–broken phases. Ward identities are typically broken by cutoffs, hence not preserved under RG flows. Even in the few cases where one has an invariant flow, truncations of the flow, which are necessary in practical calculations, spoil the Ward identities. These topics were in the focus of many discussions and some presentations. In the December workshop, Benfatto and Mastropietro showed how to avoid the use of the exact solution of the Luttinger model in RG studies, replacing them by (anomalous) Ward identities (in previous works, a reference to the exact solution had been necessary to show that the beta function vanishes). During the flow equation days, Kopper discussed a proof of perturbative renormalization of nonabelian gauge theory in the broken phase and the restoration of the Ward identities in the limit where the cutoff is removed (joint work with V.F. Müller). Enss discussed the Ward identites in fermionic RG flows and some results of transport calculations.

**4. Strong coupling problems**

This is one of the most important, yet largely unsolved problems in the theory of correlated fermions. The mathematical results cited under item 2 above and the RG calculations for applications all require that the initial interaction of the fermions is weak. This assumption is not fulfilled in most realistic systems. Instead, when model parameters are adjusted to experimental data, one finds almost always a strongly coupled situation. Studies at weak coupling remain important, particularly they seem to capture many essential features of low–dimensional systems (except that the transition temperatures are smaller and the phase diagrams get deformed), but will not suffice for a quantitative understanding of new materials. Moreover, strong couplings pose a very interesting problem for mathematical research. In the limit of an infinite on–site repulsion, the Hubbard model effectively gets a constraint of no double occupancy on the sites. There have been attempts to solve this constraint by introducing gauge fields and other degrees of freedom, but none of these approaches has led to a satisfactory theory. A number of alternative approaches to strong coupling was discussed in the first workshop. Tremblay showed results from two approximations, namely cluster perturbation theory and the so–called two–particle self–consistent approach. Both approximations seem to work well in practice but need to be understood better mathematically. Held presented dynamical mean field theory (DMFT) which

becomes exact in the formal limit of infinite dimensions of the Hubbard model. DMFT can be mapped to the single impurity Anderson model, which is not exactly solvable, but tractable numerically also at strong coupling. Mathematical problems discussed after the presentation are (i) how one could prove mathematically that DMFT becomes exact in high dimensions (ii) questions of existence and uniqueness of the solutions to the DMFT equations.

**5. Ferromagnetism**

The origin of ferromagnetism in models of itinerant electrons is at present mathematically understood only for simplified models or very special situations. At the December workshop Bach presented a new proof (in collaboration with Travaglia and Lieb) of ferromagnetism in the Hubbard–Hartree–Fock–$z$ model, in which the $SU(2)$ spin symmetry is replaced by a $Z_2$ symmetry and the ground state is obtained in a minimum over Hartree–Fock states. In another direction, B. Nachtergaele proved a number of general results about ferromagnetic Heisenberg chains that may have applications to seemingly very different problems, such as the study of asymmetric exclusion processes.

**6. Localization and random matrix theory**

Impurities in metals lead to the electrical resistivity properties observed in experiments. Even on the level of a one–electron theory, where the system is modelled by a random Schrödinger operator, e.g. the Anderson model, the mathematical problem of the existence of extended states in $d \geq 3$ has remained open. Recently much attention has focused on the mapping of the problem to a supersymmetric nonlinear sigma model, and on the related, but simpler, random matrix models. In the September workshop, Zirnbauer presented results on breaking of hyperbolic symmetries in such models (joint work with Spencer). Disertori gave two lectures on random matrix theory and continued her work with Spencer on the spectrum of band random matrices. Disertori and Zirnbauer had a number of discussions about their work. Some of the methods developed in the context of random matrix theory, such as Fyodorov's method, are expected to be useful for many–body theory.

**Invited scientists:** Stéphane Afchain, Sabine Andergassen, Volker Bach, Giuseppe Benfatto, Jean-Bernard Bru, Michele Correggi, Luca Dell'Anna, Carlo Di Castro, Margherita Disertori, Tilman Enss, Soeren Fournais, Karsten Held, Carsten Honerkamp, Stefan Kehrein, Horst Knörrer, Christoph Kopper, Edwin Langmann, Oliver Lauscher, Michael Loss, Jacques Magnen, Vieri Mastropietro, Walter Metzner, Bruno Nachtergaele, Daniel Rohe, Achim Rosch, Kurt Schönhammer, Ruedi Seiler, Robert Seiringer, Marcos Travaglia, André-Marie Tremblay, Franz Wegner, Christof Wetterich, Valentin Zagrebnov, Grigorii Zhislin, Martin R. Zirnbauer.

# Workshops organized outside the main programs

## Seminar Sophus Lie

**Organizers:** P. Michor, W. Ruppert

**Budget:** no ESI support

**Dates:** January 9 - January 10, 2004

### Report on the program

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

Dmitri V. Alekseevsky: Classification of multi-vector Poincare super Lie algebras.
Harald Biller: Holomorphically generated algebras.
Dietrich Burde: Novikov structures on solvable Lie groups.
Agota Figula: Reductive Spaces and Differentiable Loops.
Dirk Frettlöh: Symmetries of aperiodic monohedral tilings.
Hartmut Führ: New results in nonunimodular Plancherel theory.
Helge Glöckner: Differential calculus and infinite-dimensional Lie groups over topological fields.
Georg Hofmann: Ghost roots and reflection groups.
Karl H. Hofmann: Sophus Lie's Third Fundamental Theorem and the Adjoint Functor Existence Theorem.
Mathias Hofmann-Kliemt: Invariant Complex Structure on the Homogeneous Space $\mathrm{Diff}(S^1)/\mathrm{Rot}(S^1)$.
Peter W. Michor: Completing Lie algebra actions to Lie group actions.
Yurii Neretin: Variety of structures of Lie algebras on $n$-dimensional space
Aleksander Strasburger: Remarks on spherical harmonics and the Fourier transform.
Markus Stroppel: Automorphisms of unitals and hyperbolic groups.

**Participants:** D.V. Alekseevsky, M. Baake, H. Biller, D. Burde, A. Cap, G. Czichowski, A. Figula, D. Frettlöh, M. Fuchssteiner, H. Führ, G. Glöckner, S. Haller, J. Hilgert, S. Hochgerner, G. Hofmann, K.H. Hofmann, M. Hofmann-Kliemt, M.L. Linkman, P.W. Michor, Ch. Müller, Kh. Neeb, Y. Neretin, P. Plaumann, D. Poguntke, W.A.F. Ruppert, K. Sagerschnig, B. Sing, K. Strambach, A. Strasburger, M. Stroppel, M. Welk, C. Wockel, M. Wüstner.

## Winter school in geometry and physics

**Organizers:** P. Michor, J. Slovak, V. Souček

**Budget:** Budget contribution by the ESI € 1.000,–

**Dates:** January 17 - January 24, 2004

**Report on the program**

This traditional conference has taken place each January since 1980 for one week in a picturesque village in the Czech part of the Bohemian mountains. Since 1994 it has been a joint enterprise of the Czech society of mathematicians and physicists and the Erwin Schrödinger Institute for Mathematical Physics. The proceedings of this meeting will be published as a supplement of the 'Rendiconti Matematici di Palermo'.

## Ludwig Faddeev Conference

**Organizers:** A. Alekseev, N. Reshetikhin

**Budget:** ESI €10.000,–

**Dates:** March 22 - March 26, 2004

**Report on the program**

The Ludwigfest was organized as a conference celebrating the modern mathematical physics and dedicated to the 70th birthday of Prof. Ludwig Faddeev. Faddeev is one of the worlds leading scientists in the field of mathematical physics. His main achievements include:

- Understanding of the quantum mechanical 3-body scattering problem.
- Quantization of the Yang-Mills fields by means of the 'Faddeev-Popov ghosts'.
- Development of the quantum inverse scattering method (QISM) in the theory 2-dimensional integrable models.
- $R$-matrix formalism (Faddeev-Reshetikhin-Takhtajan) in the theory of quantum groups.

These subjects and their offsprings very well represent a large part of modern mathematical physics. Faddeev is also famous for creating a scientifically influential school consisting of his former Ph.D. students, and his collaborators.
The Ludwigfest meeting was a good occasion to see the panorama of the current developments in mathematical physics. Several world leading experts in the field agreed to give talks in this conference including

- Prof. J. Fröhlich (ETHZ), presenting a new approach to the boundary Conformal field theory in 2 dimensions using the 3-diemnsional topological field theory;
- Prof. R. Jackiw (MIT), discussing a new point of view on the general covariance principle;
- Prof. T. Miwa (Kyoto), explaining new quadratic relations for intertwiners in the theory of quantized affine Lie algebras;
- Prof. A. Polyakov (Princeton), opening new perspectives on conformal field theory and string theory.
- Prof. W. Thirring (Vienna), re-examining the question of subalgebras in the Weyl algebra.

Among other presentations there was a number of talks by former Ph.D. students of Faddeev including Prof. I. Arefeva (Moscow), Prof. S. Shatashvili (Dublin), Prof. M. Semenov-Tian-Shansky (Dijon), Prof. F. Smirnov (Paris), Prof. L. Takhtajan (Stony Brook), Prof. V. Tarasov (St. Petersburg), Prof. A. Venkov (Aarhus)

The most recent works of Faddeev are devoted to the theory of 'knotted solitons'. These structures were predicted by Faddeev about 25 years ago. Recently, there was a lot of analytical and numerical evidence supporting the existence of knotted solitons as solutions of certain field theoretic models. New results on this topic were presented by J. Hietarinta (Turku) and by A. Niemi (Uppsala).

In summary, Ludwigfest was a very interesting and inspiring meeting with an exciting scientific program animated by some of the world's leading figures in the field of mathematical physics, and with an interesting social and historical dimensions.

**Participants:** Anton Alekseev, Irina Aref'eva, Olivier Babelon, Lioudvig Faddeev, Jürg M. Fröhlich, Klaus Hepp, Jarmo Hietarinta, Jens Hoppe, Roman W. Jackiw, Rinat Kashaev, Jean Michel Maillet, Tetsuji Miwa, Antti Niemi, Stanislav Pakuliak, So-Young Pi, Alexandre Polyakov, Nicolai Reshetikhin, Robert Schrader, Ruedi Seiler, Michael Semenov-Tian-Shansky, Samson Shatashvili, Andrey Slavnov, Fedor Smirnov, Daniel Sternheimer, Leon Takhtajan, Vitaly Tarasov, Alexei Venkov, Alexandre Volkov.

## Summer School and Workshop on Nonlinear Wave Equations

**Organizers:** Y. Brenier, S. Klainerman, N. Mauser, S. Selberg

**Budget:** ESI € 11.475,–, external sources: EU network HYKE and WPI € 10.000,–

**Dates:** July 7 - July 14, 2004

### Report on the program

About 35 participants attended, many students from Italy and France and the local PhD students of the Viennese Wissenschaftskolleg Differential equations. Also most guests of the parallel program on 'Singularity formation in non-linear evolution equations' participated with enthusiasm.

The backbone of the school part were the following courses:

Sigmund Selberg: Bilinear estimates, null forms and applications to nonlinear wave equations
Markus Keel: Introduction to regularity properties of semilinear Schrödinger equations

They were followed by the "overview lectures":

Alan Rendall: Introduction to the Einstein equations
Philippe LeFloch: Well-posedness theory for nonlinear hyperbolic systems

These were accompanied by shorter presentations:

Yann Brenier: Going beyond concentration singularities for the Born-Infeld equations and their high field limits
Sergiu Klainerman: On the $L^2$-bounded curvature conjecture
Alexander Komech: On attraction to Solitons in Relativistic Nonlinear Wave equations
Norbert J. Mauser: From Dirac-Maxwell to Vlasov-Poisson: Klainerman-Machedon meets Wigner

Israel Michael Sigal: Soliton dynamics in nonlinear Schrödinger equation
Jason Metcalfe: Nonlinear wave equations in exterior domains
Mihalis Dafermos: A proof of Price's law for the collapse of a self-gravitating scalar field
Paul Godin: The lifespan of a class of smooth compressible flows
Damiano Foschi: Maximizers for Strichartz inequalities

**Other Participants:** Zakaria Hachemaoui, Sandra Lucente, Simona Candela, Stefano Zappacosta, Paolo Antonelli, Mirko Tarulli, Julian Weiss, Tatiana Dudnikova, Lukas Neumann, Christoph Sparber, Michael Wernig-Pichler.

## Workshop on Penrose Inequalities

**Organizers:** R. Beig, P. Chrusciel, W. Simon

**Budget:** ESI €9.000,–

**Dates:** July 26 - August 7, 2004

**Preprints contributed:** [1464], [1488], [1506], [1552], [1555], [1564]

### Report on the program

The workshop was attended by 9 researchers, all of whom had participated in the 2003 workshop. Unfortunately some of the key participants of the 2003 workshop could not attend (in particular Schoen, Bray, Ilmanen), as they already had other plans when the follow-up workshop was confirmed. Nevertheless the workshop went very well, with intensive discussions and collaborations, and has been very useful. None of the strategies developed for tackling the general Penrose Inequality has borne fruit so far, but there is intensive work by several researchers towards settling the problem.

The highlights of the seminars included a talk by Malec, who presented numerical evidence that one conceivable version of the Penrose inequality could not be true, as well as a talk by Mars, which discussed stability of apparent horizons. Several talks were concerned with black hole initial data, directly related to the problem at hand.

The cross-interaction with the parallel workshop 'Singularity formation in non-linear evolution equations' was excellent in both directions, with almost all seminars from each workshop being attended by most participants of the other one.

**Participants:** Robert Beig, Piotr T. Chrusciel, Sergio Dain, Jacek Jezierski, Szymon Leski, Edward Malec, Marc Mars, Niall O'Murchadha, Walter Simon.

## Workshop on Stochastic and Deterministic Dynamics in Equilibrium and Nonequilibrium Systems

**Organizers:** C. Dellago, H. Posch

**Budget:** ESI €9.000,–

**Dates:** August 25 - August 28, 2004

**Report on the program**

The workshop at the Erwin Schrödinger Institute in Vienna addressed a number of fundamental and hotly debated problems in modern statistical physics: the characterization of nonequilibrium systems in stationary states; the significance of dynamical or stochastic methods for the generation of such states; the fluctuations encountered near and far from equilibrium; nonequilibrium work theorems for the computation of free energy differences of mesoscopic systems and their relation to the fluctuation theorems mentioned above; the application of dynamical systems theory to fluids and solids and, in particular, the investigation of the Lyapunov instability for such systems; and nonlinear dynamical systems and transport theory for fluids and solids. These topics were complemented by talks on recent ideas about the onset of turbulence, on decoherence and chaos in quantum mechanical systems, and on stochastic dynamics.

In total, there were 33 lectures by leading experts, who were instrumental for the evolution and the recent successes witnessed in this field. Most lectures were followed by stimulating discussions, which lasted through the breaks and continued in the evenings. The workshop was also attended by about 20 young researchers, graduate students and post docs, from various European countries who also contributed to the discussions.

The Erwin Schrödinger Institute for Mathematical Physics in Vienna provided an ideal setting for the workshop. The spatious and pleasant common room, the numerous blackboards in the hallway, the offices provided for most of the participants, the technical infrastructure, and the excellent organization and support by the staff of the Institute, all added up to an atmosphere most conducive to scientific exchange. Most of the participants agreed that this workshop constituted by far the most comprehensive and stimulating meeting on nonequilibrium statistical mechanics in 2004.

## Scientific Report:

Recently, various fluctuation theorems for systems out of equilibrium have been formulated. The significance of such theorems lies in the fact that very little is known on such systems: the fluctuation formulas constitute one of the very few available exact results. The first fluctuation theorem (FT) was formulated in 1991 by D.J. Evans et. al. (ANU, Canberra, Australia) for a very restricted class of stationary far from equilibrium systems, and was given a more thorough theoretical basis by G. Gallavotti (Rome) et. al. in 1995. In the following years it was theoretically extended, and as verified by computer simulations of very simple models. Attempts of an experimental verification, most notably by S. Ciliberto (ENS Lyon, France), were partially successful.

In the workshop, which brought together almost all of the leading scientists in the world having contributed to this important topic (with the notable exception of G. Gallavotti, Rome), it became clear from the discussions, however, that the theorem applies only to a very carefully defined set of fluctuation functions and that the theorem might fail for systems very close to equilibrium (which means that the assumptions entering its derivation are not obeyed in this case).

Recently, a whole set of so called transient fluctuation theorems (TFT) was derived by D.J. Evans (ANU) and collaborators, which are applicable to systems, which start with equilibrium and are driven to nonequilibrium states by external perturbations. The sometimes very vivid discussions during the workshop were instrumental for identifying the fluctuating functions

required for a correct interpretation of various experimental tests provided by some of the participants (S. Ciliberto, Lyon; E.M. Sevick, Canberra). A most illustrative analysis of current fluctuations observed with electrical resistors was provided by R. van Zon (Rockefeller U.).

From the proceedings of the workshop it became clear that there is a very close connection of the TFTs with another very modern development in statistical mechanics, namely the derivation of work theorems by C. Jarzynski (LANL, Los Alamos) for the computation of free energy differences by nonequilibrium methods. These theorems have been rederived and interpreted by G. Crooks (Berkeley) and G. Hummer (NIH), and extended to quantum mechanical systems by S. Mukamel (Irvine). All these authors were present at the workshop. The discussions focused on recent applications of the theory to biophysical systems such as the stretching of RNA molecules by C. Bustamante (Berkeley). As was the case with the TFTs, the workshop brought a clarification of many aspects of the theory, particularly with respect to the proper definition of the fluctuation functions. Although hotly contested by E.G.D. Cohen (Rockefeller U.) and P. Häggi (Augsburg), the applicability of these theorems to far from equilibrium states (which, unfortunately, are not readily accessible to experimental tests at present) was agreed on by most of the participants.

The Lyapunov instability of fluids, and Lyapunov modes in particular, were other topics discussed in detail. After the discovery of Lyapunov modes by H.A. Posch (U. Vienna) and collaborators in 1998, various groups have worked on this topic to understand the origin and significance of these modes. All active research groups were represented at the workshop: H. A. Posch and Ch. Forster (U. Vienna), J.P. Eckmann and E. Zabey (U. Geneva), H. van Beijeren (U. Utrecht), G. Morriss and T. Taniguchi (U. Sydney), and G. Radons and H. Yang (TU Chemnitz). The theoretical basis and the role the conservation laws and boundary conditions play in this phenomenon was established, and possible extensions to more general interaction potentials were discussed. It is hoped that the Lyapunov modes provide a new theoretical tool to study phase transitions and the dynamics of condensed matter.

Stochastic processes and the fluctuations and the characterization of stationary nonequilibrium systems dominated the last day of the workshop. D. Mukamel (Weizmann I., Rehovot) demonstrated that driven systems may exhibit phenomena like phase separation whereby a macroscopic highdensity phase coexists with a low density one. L. Rondoni presented an extension of the Onsager Machlup theory to nonequilibrium steady states, resulting in an additional term in the 'adjoint' hydrodynamic equations (describing the growth of fluctuations), which has no counterpart in the usual hydrodynamic equations (describing the decay of fluctuations). Thus, growth and decay times of fluctuations in statioanary nonequilibrium ensembles may possibly be different. R. Klages (U. London) critically reviewed the relation between phase space contractions, computed with dynamical time reversible thermostats, and thermodynamic entropy production and claimed that there is no equivalence of ensembles concerning chaotic properties. P. Gaspard (U. Brussels) gave an overview of the different bridges between dynamical systems theory and the theory of irreversible processes, including the escaperate formalism for transport coefficients, the fluctuation theorem, and a recent result showing that, in nonequilibrium steady states, the entropy production is related to the difference between a timereversed entropy per unit time and the standard entropy per unit time by Kolmogorov and Sinai. The nonvanishing of the entropy production appears as a consequence of the singular character of the nonequilibrium steady states and their hydrodynamic modes. Finally, Wm.G. Hoover (LLNL) summarized new results for the phase space contraction associated with heat flow on two dimensional lattices.

**Assessment of the results and impact of the workshop on the future direction of the field:**

Nonequilibrium systems are among the most challenging topics of current research in statistical physics. The workshop at the ESI was attended by almost all of the leading scientists working on fluctuation formulas and work theorems. It established a common basis and 'language' for future experimental and theoretical work in that field. For example, recent experiments of S. Ciliberto and coworkers were reevaluated during the workshop and were found to be in good agreement with theoretical predictions. Furthermore, all European groups have been brought up to date with current important experimental and theoretical work in Australia and the US. And the very constructive criticism most notably formulated by E.G.D. Cohen was the topic of many discussions. It is fair to say that, as a consequence, the general understanding of the fluctuation phenomena in nonequilibrium states has been considerably improved and extended. The workshop also provided an overview and a summary of all the current activities concerning Lyapunov modes for many particle systems. The characterization of these modes, and their physical basis, has been established beyond doubt, and the agreement between simulation results and theory has been demonstrated at the workshop, at least for low density particle systems with hard body interactions. The situation for softparticle systems still is not completely satisfactory. Further work will be necessary, before applications to various physical processes (such as phase transitions and the glass transition) may be addressed. At least four European groups are currently working on that goal.

The characterization of stationary nonequilibrium processes has been another strongly debated topic of the workshop. The existence of fractal structures in phase space has been frequently attributed to the use of timereversible dynamical thermostats. Recent results with stochastic thermostats by H. A. Posch and collaborators, which were also discussed among the participants, demonstrate that it is possible to formulate nonequilibrium transport in this case with the same qualitative results the existence of a fractal attractor in phase space and a well established link with the rate of entropy production. In these discussions, the presence of experts of stochastic dynamics was most fruitful. With ever smaller molecular devices and machines being developed, a close collaboration between the 'stochastic community' and groups mostly concerned with processes on the molecular scale seems the best warranty for a speedy evolution of this field.

**Participants:** Debra Bernhardt, Sergio Ciliberto, E.G.D. Cohen, Gavin Crooks, Predrag Cvitanović, Francois Diviaud, Jacob Robert Dorfman, Bérengére Dubrulle, Jean Pierre Eckmann, Denis J. Evans, Anselmo Garcia Cantu, Pierre Gaspard, Nikolaj Georgi, Thomas Gilbert, Peter Hänggi, Bill Hoover, Carol Hoover, Gerhard Hummer, Akito Igarashi, Dennis Isbister, Chris Jarzynski, Changho Kim, Rainer Klages, Eok Kyun Lee, Hans G. Loew, Dmitry G. Luchinsky, László Mátyás, Max Meinhart, Emil Mittag, Gary Morriss, David Mukamel, Shaul Mukamel, Heide Narnhofer, Günter Radons, Matthew Reames, Lamberto Rondoni, Edie Sevick, Peter Talkner, Tooru Taniguchi, Henk Van Beijeren, Ramses Van Zon, Stephen Williams, Hongliu Yang, Emmanuel Zabey.

## Workshop on Stochastic processes from physics and biology

**Organizers:** A. Wakolbinger (Frankfurt, Senior Research Fellow ESI)

**Budget:** external sources DFG-Frankfurt €5.000,– and EURANDOM €1.200,–

**Dates:** November 26 - November 27, 2004

**Report on the program**

The idea to organize the ESI workshop 'Stochastic processes from physics and biology' (November 26-27, 2004) was stimulated by the exellent reminiscence to the 'Special term on population genetics and statistical physics' organized at ESI 2002/03 by Ellen and Michael Baake (now Bielefeld) and Reinhard Bürger (Vienna). The November 2004 workshop was co-organized by the bilateral research group 'Mathematics of Random Spatial Models from Physics and Biology', which is funded by the German Research Council and the Netherlands Organisation for Scientific Research and consists of groups in Eindhoven (EURANDOM), Berlin (Weierstrass-Institute), Bielefeld, Erlangen and Frankfurt. The topics of the workshop talks included spatial population models, infinite particle systems, metastability, random trees, and random matrices. In addition to the three keynote lectures (given by Dawson, Etheridge and den Hollander) eight lectures were given by young scientists from the research group. Titles of talks, list of participants and abstracts can be found at http://www.esi.ac.at/activities/archive/Stochastic2004.html. A follow-up workshop in this series, co-organized by Matthias Birkner, will soon take place at the WIAS Berlin (http://www.wias-berlin.de/workshops/rsmpb05/ )

**Participants:** Wolfgang Angerer, Elena Shmileva, Ellen Baake, Matthias Birkner, Anton Bovier, Donald Dawson, Jiri Cerny, Michael Eckhoff, Alison Etheridge, Jonas Erb, Alessandra Faggionato, Barbara Gentz, Friedrich Götze, Andreas Greven, Ulrich Haböck, Frank den Hollander, Martin Hutzenthaler, Götz Kersting, Gregory Maillard, Heinrich Matzinger, Reda-Juerg Messikh, Pleuni Pennings, Peter Pfaffelhuber, Leona Schild, Kristan Schneider, Justine Swierkot, Rongfeng Sun, Alexander Tikhomirov, Anton Wakolbinger, Anita Winter.

## 1st Vienna Central European Seminar on Particle Physics and Quantum Field Theory: Advances in Quantum Field Theory

**Organizers:** H. Hüffel (Vienna)

**Budget:** ESI €2.100,–, also supported by the Austrian Federal Ministry for Education, Science and Culture and by the Institute for High Energy Physics of the Austrian Academy of Sciences

**Dates:** November 26 - November 28, 2005

**Preprints contributed:** [1517], [1520], [1521], [1522], [1523], [1524], [1591], [1592], [1609], [1611]

**Report on the program**

**Advisory Board:**

A. Bartl (Vienna), H. Grosse (Vienna), W. Majerotto (Vienna), E. Scheidegger (Vienna), V. Schomerus (Saclay)

The subject was centred on field theoretic aspects of string dualities. Further lectures regarding supersymmetric gauge theories, quantum gravity and noncommutative field theory complemented the program.

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

**Invited Speakers:**

G. Arutyunov (Golm): Integrability in the Gauge / String Correspondence
J. de Boer (Amsterdam): Non-perturbative quantum field theory and string theory
M. Dimitrijevic (Munich):Deformed Bialgebra of Diffeomorphisms
J. Ellis (CERN): Searching for Supersymmetry at the LHC and Elsewhere
W. Lerche (CERN): Quantum geometry of D-branes and nonperturbative field theory
R. Loll (Utrecht):Four-dimensional spacetime from causal nonperturbative quantum gravity
J. Louis (Hamburg): String Theory, Supersymmetry and Geometry
H.-P. Nilles (Bonn):Heterotic Brane World
D. Olive (Swansea):Minimal Representations and Freudenthal Triple Systems
S. Pokorski (Warsaw): The Origin of the Fermi Constant - a Challenge for the LHC

**Supported Junior Scientists:**

A. Anisimov (Munich): Some Issues in the Ghost Condensation Scenario
D. Grumiller (Leipzig): BPS-kink and More Global Solutions of the Chern-Simons Supergravity Term
A. Ozer (Dublin): Compactifications with S-duality Twists
S. Reffert (Munich): Soft SUSY Breaking Terms from D7-Branes with Fluxes
E. Regos (Budapest):Casimir Effect: Running Newton Constant or Cosmological Term
H. Steinacker (Munich):Finite Gauge Theory on Fuzzy CP2
L.Tagliacozzo (Barcelona):Results about U(1) Lattice Gauge Theories from Seiberg Witten Duality
G. Toth (Budapest):On N=1 Supersymmetric Boundary Bootstrap
J. Wagner (Warsaw):Little Supersymmetry with Heavy sfermions
R. Wulkenhaar (Leipzig):Renormalization of Noncommutative $phi^4_4$-theory to All Orders

**Further speakers:**

I. Andric (Zagreb): Matrix Model Dualities in the Collective Field Formulation
L. Bergamin (Vienna):Generalized Complex Geometry and the Poisson Sigma Model
E. Scheidegger (Vienna):Non-perturbative Effects in Heterotic String Compactifications
E. Sharpe (Salt Lake City):Gauging Noneffective Group Actions and Mirror Symmetry

**Poster Session:**

C. Bhmer (Vienna):Torsion and the sign problem of the cosmological constant
G. Bene+G. Helesfai(Budapest):Spectral properties of the area operator in quantum gravity
M. Cvitan (Zagreb):Conformal entropy and stationary Killing horizons
J. Hosek (Prague): A model of flavors
S. Ilijic (Zagreb): Gravitational field induced by spherically
symmetric distributions of ECD in Einstein-Maxwell theory
M.+V. Martinis (Zagreb): Quantum Horizons and Space-Time Non-Commutativity

**Discussion Sessions:**

Two sessions, chaired by H. Grosse (Vienna) and E. Scheidegger (Vienna), respectively.

Webpage:http://www.univie.ac.at/vienna.seminar/index04.html

## Workshop on Automorphic Representations and Related Topics

**Organizers:** J. Schwermer (Vienna)

**Budget:** ESI € 5.100,–

**Dates:** December 6 - December 9, 2004

### Report on the program

The workshop focused on recent developments in the theory of automorphic forms, particularly those involving interactions with geometry, number theory and representation theory. It included the following topics:

- the interplay between local representation theory and its global applications in the theory of automorphic forms
- arithmetic aspects in the use of the Arthur-Selberg trace formula for constructing automorphic forms
- special values of automorphic L-functions and related zeta integrals
- cohomology of arithmetic groups as a tool in studying possible relations between automorphic forms and the arithmetic of algebraic varieties resp. the geometry of locally symmetric spaces
- related questions in the algebraic theory of vertex algebras

### Program:

M. Tadic (Zagreb): On Jacquet-Langlands correspondences and unitarity
J. Rohlfs (Eichstätt): Cohomology of arithmetic groups - non-analytic aspects
W. Singhof(Düsseldorf): On the cohomology of Bianchi groups
G. Muic (Zagreb): Construction of residual automorphic forms and isolated unitary representations I, II
M. Primc (Zagreb): Combinatorial Identities and vertex operator algebras
St. Caparelli (Rom): Principal subspaces and recursion formulas
T. Ishii (Tokyo): Whittaker functions on Sp(2,R) and archimedean zeta integrals
D. Adamovic (Zagreb): On the representation theory of certain W-algebras
T. Hayata (Wien): Automorphic representations and the cohomology of arithmetic subgroups of SU(2,2)
Y.Ishikawa (Okayama): On standard L-functions for generic cusp forms on SU(2,1)

**Participants:** Drazen Adamovic, Dietrich Burde,Stefano Caparelli,Gerald Gotsbacher, Hans Gmasz, Marcela Hanzer,Takahiro Hayata, T. Ishii, Y. Ishikawa, Christian Lacher, Joachim Mahnkopf,Goran Muic,Mirko Primc, Jürgen Rohlfs, Joachim Schwermer,Wilhelm Singhof, A. Stefanov.

# Senior Research Fellows Program

To stimulate the interaction with the local scientific community the ESI offers lecture courses on an advanced graduate level. These courses are taught by Senior Research Fellows of the ESI whose stays in Vienna are financed by the Austrian Ministry of Education, Science and Culture and the University of Vienna. The coordinator of this program was Joachim Schwermer.

This year's program concentrated on the following lecture courses:

**Peter van Nieuwenhuizen** (SUNY at Stony Brook), Summer 2003/January 2004, on:
$N = 1$ *and* $N = 2$ *supersymmetry and supergravity*

**Jürgen Rohlfs** (University Eichstätt), Winter 2003/January 2004, on:
*Algebraic groups over number fields and related geometric questions*
[for reports on the lecture courses of Peter van Nieuwenhuizen and Jürgen Rohlfs please see the Scientific Report for 2003]

**Werner Ballmann** (Universität Bonn), Summer 2004, on:
*Über die Geometrie der Gebäude - On the geometry of buildings*

**Jürgen Fuchs** (Karlstadt University, Sweden), Summer and Fall 2004, on:
*Conformal Field Theory*

**Manfred Salmhofer** (Universität Leipzig), Fall 2004, on:
*Renormalization Theory - Analysis and Applications*

**Vlatko Vedral** (Imperial College, London), Fall 2004, on:
*Foundations of Quantum Information*

**Boban Velickovic** (Jussieu, Paris), Fall 2004, on:
*Introduction to Descriptive Set Theory*

**Anton Wakolbinger** (Universität Frankfurt), Winter 2004/January 2005, on:
*Stochastische Prozesse aus der Populationsgenetik - Stochastic Processes from Population Genetics*

There were many informal meetings between the lecturers and the participants of the courses in which they discussed and elaborated on the ideas and results presented in the lectures.Some of the courses are going to appear in an extended form in the ESI book series "ESI Lectures in Mathematics and Physics" published by the European Mathematical Society.

We include descriptions of the content of the lecture courses followed by a short report covering the research activities of the Senior Research Fellow in question.

## Werner Ballmann: On the Geometry of Buildings

**Course:** In my class I discussed the geometry of Tits buildings. After a short introduction into buildings, I started with a general discussion of metric spaces with an emphasis on ideas and methods relevant in global Riemannian geometry. The next topic were metric spaces with upper curvature bounds in the sense of Alexandrov and the generalization of results from Riemannian geometry to such spaces, notably the theorem of Cartan–Hadamard and Cartan's fixed point theorem for CAT(0)–spaces. I proved that spherical and Euclidean buildings, endowed with their natural metrics, are spaces with curvature at most 1 and 0, more precisely, that they are

CAT(1) and CAT(0), respectively. I continued with an example of a Euclidean building due to Iwahori and Matsumoto. Finally I introduced special geodesic flows on Euclidean buildings and discussed applications to the fundamental groups of their compact quotients. My notes of the course are available as ESI preprint [1511].

**Research:** Christian Bär (Universität Potsdam) visited from March 17 to March 24. We work on boundary problems for Dirac type operators. Our interest is in the direction of regularity questions and index formulas. We found a very useful type of regular boundary conditions with an easy deformation theory. The deformation theory is very valuable in such problems as relative index theory and boundary theory at infinity. We believe that our type of boundary condition is the most general possible regular type.

With Klaus Schmidt (Erwin–Schrödinger–Institut) I discussed the $\mathbb{Z}^2$–shift operator on $G$–valued $\mathbb{Z}^2$–chains of finite type, where $G$ is a compact Lie group. In the case where $G$ is Abelian, topological entropy and other dynamical invariants of the shift have been studied successfully. We concentrate on the case where $G$ is not Abelian. This is a new project, and we started it during my stay at the ESI.

I also worked on an ongoing project concerning the existence of normal free subgroups of fundamental groups. In his seminal paper on hyperbolic groups, Gromov asserts the existence of normal free subgroups in fundamental groups of closed manifolds of (strictly) negative sectional curvature. (His argument is not quite complete.) I managed to extend his argument to the case of closed manifolds of rank one. During my stay at the ESI I worked on other ways of extending and varying Gromov's argument.

**Preprints contributed:** [1511]

### Jürgen Fuchs: Conformal Field Theory

**Course:** The study of conformal field theories (CFTs) – two-dimensional quantum field theories whose correlators are covariant under conformal transformations – has become an important topic both in theoretical physics and in mathematics. Developments in this area are e.g. closely connected with the study of vertex algebras, monstrous moonshine, quantum groups and weak Hopf algebras, affine Lie algebras, and invariants of knots and links in three-manifolds. CFT also has numerous applications in physics, e.g. to critical systems in statistical mechanics, the Kondo effect, quantum Hall fluids, critical percolation and random walks, and string theory.

Models of rational CFT, for which the chiral symmetry algebra has only a finite number of irreducible representations, are solvable in the sense that they furnish a finite collection of data which completely determine all their correlation functions, for arbitrary field insertions and on any 'world sheet'. After the pioneering fundamental results by Belavin-Polyakov-Zamolodchikov 1984, and Moore-Seiberg and Cardy 1989, for a long time much effort has been devoted to aspects of this solvability for specific models or classes of models. In contrast, the quest for a deeper understanding of model-independent aspects of CFT was significantly less intense.

In recent years, however, much new insight into the structure of rational CFT was gained, both for 'chiral' CFT, i.e. CFT on surfaces with complex structure, and for 'full' CFT, i.e. CFT on real world sheets, which have a conformal structure but are not necessarily orientable and may have non-empty boundary. As a consequence, while work on applications of CFT often involves heuristic concepts that have their origin in the respective area of application, meanwhile basic

aspects of rational CFT can indeed be analyzed rigorously, allowing one to make precise general statements and prove them.

Progress in chiral CFT arose from new results in the theory of vertex algebras and their representations (e.g. Huang-Lepowsky, Dong-Li- Mason, Nagatomo-Tsuchiya) and a better understanding of algebro-geometric and functional-analytic aspects of conformal blocks (e.g. Frenkel-Ben Zvi, Huang). For full CFT, there have been new developments in the $C^*$-algebraic setting, in particular aspects of modular invariants (Xu and Böckenhauer-Evans-Kawahigashi, based on earlier work by Longo-Rehren), as well as in a novel approach to CFT via non-commutative algebra in tensor categories and three-dimensional topological field theory (Kirillov-Ostrik, Müger, Felder-Fröhlich-Fuchs-Schweigert, Fuchs-Runkel-Schweigert). The latter approach can in particular be used to give a universal construction of arbitrary correlations functions on any world sheet, including also e.g. effects of boundary conditions and defect lines, by which basic aspects of the correlators are expressed in terms of invariants of links in three-manifolds.

The purpose of the course was to provide an introduction to some of these new developments, at a level accessible to researchers from neighboring fields and to graduate students. In particular, enough information on various aspects of tensor categories and topological field theory was given to allow for a basic understanding of the construction of correlation functions by Fuchs-Runkel-Schweigert.

A more specific goal was to give some relevant background information that facilitated non-experts to follow the talks that were given in the framework of the ESI program "Tensor categories in mathematics and physics", which had its main activities in the two weeks after the course.

**Course contents:** The course consisted of 12 lectures of 90 minutes duration.
The following topics were treated:

1) The world sheet:
   geometry of surfaces; Teichmüller and moduli spaces; mapping class groups; complex cover of a world sheet; relative modular group.

2) Vertex algebras:
   axioms and their role in CFT; WZW and other examples; representation theory; rationality.

3) Chiral CFT and fusion rules:
   chiral blocks; Ward identities, in particular for WZW models; fusion rings; modular transformations and the Verlinde conjecture; chiral factorization.

4) Full CFT:
   boundary conditions and defect lines; bulk fields, boundary fields and disorder fields; correlation functions versus chiral blocks; locality and factorization constraints; Ishibashi and Cardy boundary states; the bulk-boundary operator product.

5) Torus and annulus partition functions:
   modular invariance; extension and automorphism invariants; simple current invariants; the A-D-E classification for the sl(2) WZW model.

6) 3-d TFT:
   extended surfaces; cobordism categories; axioms of TFT; mapping class group action; gluing homomorphisms.

7) Tensor categories:
categories and monoidal structures; braiding, twist and duality; modular tensor categories; non-commutative algebra in tensor categories.

8) Full CFT via TFT and tensor categories:
the construction in the Cardy case; Frobenius algebras; basic ideas of the construction in the general case; example: partition functions.

**Research:** My research concentrated on aspects of a long-term project that is concerned with a model-independent description of correlation functions in rational conformal field theory. It combines tools from three- dimensional topological field theory with the theory of Frobenius algebras in modular tensor categories and their representation theory. More specifically, I worked on obtaining explicit formulas for the structure constants of the various types of operator product expansions that exist among bulk, boundary and defect fields (with I. Runkel and C. Schweigert), and on finishing the proof of the modular invariance and factorization properties of our prescription for correlation functions (with J. Fjelstad, I. Runkel and C. Schweigert).

In addition I examined properties of several mathematical structures – like weak Hopf algebras, certain 2-categories, and the Picard groups of bimodule categories – that are needed for a systematic understanding of these operator product expansions and for a description of order-disorder symmetries in CFT (with J. Fröhlich, I. Runkel and C. Schweigert).

I also investigated homological aspects of the associativity constraint in tensor categories which are related to the presence of invertible objects. This work is done in collaboration with A. Ganchev.

During the last part of the first period of my stay, all the collaborators just mentioned were visiting ESI, attending the ESI program "Tensor categories in mathematics and physics". I. Runkel also had a second period of overlap with me, when he participated in the ESI program "String theory in curved backgrounds and conformal field theory". Furthermore, during the Tensor categories program I had intensive discussions of aspects of my research with several other participants, in particular with A. Bruguières, A. Kirillov Jr. and B. Pareigis; I expect that these discussions will be very beneficial in the future.

**Web site:**
`http://www.esi.ac.at/activities/archive/CFT-SS04.html`
Links to relevant literature are provided at
`http://www.ingvet.kau.se/~jfuchs/lect/wien04_lit.html`
**Dates:**
April 29 – June 29, and September 9 – September 24, 2004

**Preprints contributed:** [1543],[1565]

### Manfred Salmhofer: Renormalization Theory - Analysis and Applications

**Course:** I gave a graduate course consisting of twelve two–hour lectures on *Renormalization Theory - Analysis and Applications*. The lectures took place biweekly Thursdays, 14:00-16:00 and Fridays, 10:00-12:00. I also offered a seminar accompanying this course. It took place Friday, 12:30–14:00 and at convenience of the pariticipants. We mainly discussed questions of the participants, as well as exercise problems that I had posed in the course.

The average number of participants in the lectures was 10 to 15, among them about 5 students on the diploma and doctoral level.

*Course contents.* Introduction to critical phenomena; Kadanoff–Wegner blockspin renormalization group. Explanation of universality classes as basins of attraction of fixed points and of critical exponents as eigenvalues of the derivative of the RG map. Examples. A mathematically rigorous definition of functional integrals. Gaussian integrals, Wick ordering, Feynman graph expansions for the evaluation of partition functions. Connected graph theorems for the logarithm of the partition function. Effective actions and setup of the renormalization group. Semigroup structure of the renormalization group and its consequences for the vertex functions. Renormalization group differential equation (RGDE) in Polchinski and Wick ordered form. Graphical structure of the equation. Its relation to perturbation expansions by Brydges–Kennedy formulas. Proofs of perturbative renormalizability in 2,3, and 4, dimensions. Renormalization as the change of boundary conditions for the flow. Beta functions and flows of the coupling constants as functions of the scale. Infrared asymptotic freedom of scalar theory in four dimensions. Ultraviolet asymptotic freedom in the Gross–Neveu model. Discussion and outlook on nonperturbative constructions.

The subjects listed above are not all of those that I had intended to cover in the course, but I found it more important to treat all topics in depth and give clean definitions and complete mathematical proofs than to browse many subjects but skip proofs. The feedback from the audience confirmed this choice. Teaching the course also gave me the opportunity to rethink a number of issues and further simplify the proofs.

**Research:**

1. I finished work on a paper joint with Honerkamp, Metzner, and Lauscher, on Renormalization Group Flows into Phases with Broken Symmetry,[1533], published in Progress in Theoretical Physics 112 (2004) 943. This paper addresses how to avoid the divergence of flows in situations where symmetry breaking takes place, and it allows for the first time to continue the fermionic RG flows into the symmetry–broken phase. For the method to work it is crucial that certain Ward identities are preserved in the flow. We show that in the BCS model, the exact result for the gap is reproduced by the flow. A number of generalizations is under investigation.

2. I continued a project on an RG analysis of a transition between superconductivity and ferromagnetism in the two–dimensional Hubbard model at the van Hove filling. The existence of such a transition is predicted by the temperature–flow RG developed in collaboration with C. Honerkamp. The present project, joint with C. Husemann and O. Lauscher, aims at a more detailed study of this transition. To this end, a combination of fermionic and bosonic RG techniques is being developed.

3. I worked on the *dynamical renormalization group differential equation*, where self–energy effects are taken into account in the propagator automatically in the equation. This provides an efficient way of taking into account the deformation of the Fermi surface in many–fermion field theory, a point which is often treated incompletely or not at all, even in the mathematical literature. Although this dynamical adjustment of the propagator is of course a natural idea, the most obvious choices how to choose the scaled propagators do not work well in the continuous RG equation, and finding a useful setup was not trivial. The method can also be combined with complete or partial Wick ordering, and has proven useful in practical and mathematical studies of models. A preprint is in preparation.

4. I worked on the completion of a paper on Fermi surface flows and Fermi surface regularity, joint with Walter de Siqueira Pedra (Leipzig). We study a flow of Fermi surfaces generated

by a variant of the method discussed in item. The flow of the Fermi surface is constructed by convergent expansions; regularity is shown using a combination of tree and arch expansions.

5. I worked on completing a further paper, joint with Erdős and Yau on the long–time behaviour of the time evolution of the Anderson model. The main result is that on time scales beyond the kinetic time scale, the Wigner function satisfies a diffusion equation. The method of proof is by tight estimates on the contribution of very large Feynman graphs to a Duhamel expansion in which the fermion propagator is renormalized by including lowest order self–energy terms in the propagator.

Besides that I had numerous interactions with other participants, in particular I explained a number of technical points of the Fermi surface construction mentioned in item to A. Giuliani, and had interesting discussions with E. Langmann about effective fermionic models that he derived for studying the quantum Hall effect. With C. Honerkamp, I started investigating the derivation of the Eliashberg equations for superconductors from the renormalization group. In this case, one has to take the forward scattering terms into account. With T. Enss and W. Metzner, I continued a project on general properties of Ward identities in RG flows.

**Preprints contributed:** [1533]

### Vlatko Vedral: Foundations of Quantum Information

**Course:** I have taught a course on Foundation of Quantum Information at ESI. There have been between 20 and 30 students attending this course. My course has also been filmed by student from the group of Prof. Vladimir Buzek in Bratislava (I have been asked for a permission by them and I was happy to grant it). These videos will also be available on the web (they will be accessible to everyone on the website of Prof. Buzeks group). In addition, I have been writing lecture notes that are also available on the web (www.esi.ac.at/qinfo/lectures.pdf). My plan is to convert these into a book that will be published either as a monograph or as lecture notes. The audience has been diverse, and I have had to tailor my course to physicists, engineers as well as mathematicians. I think this has had a mixed success, but the comments that I have received directly from many people have been positive. In addition I have held seminars (on average 2 hours every second week) and they have been either presentations by attendants, guest lectures, or open questions and issues related to the course.
Here are the details of the topics I have covered in my course (the numbers is brackets are the number of lectures dedicated to the corresponding topic):

Syllabus: Classical Information theory, Shannons theorems (2), Qubits, Quantum Data Compression (2), Entropy and Information (2), General measurement: POVM (2), Holevo bound (2), Entanglement, Bells Inequalities (2), Dense Coding, Teleportation (2), Mixed States and Their Entanglement (2), Entanglement Witnesses, Measures of Entanglement (2), Computational Complexity, Deutschs Algorithm (2), Shors algorithm, Interferometers as computers, Black-box complexity formulation, Search Problem (2), Implementations of quantum computation and the basics of quantum error correction (2).

**Research:** In terms of research I have been mainly working on the topic of macroscopic entanglement. I have written two papers on this topic (both of them are on the Los Alamos archive), one of which has been reviewed by the New Scientist the British counterpart of the Scientific American. The other paper, in collaboration with Profs. Caslav Brukner and Anton

Zeilinger, has been submitted to Physical Review Letters. In addition I have a very successful collaboration with the experimental group of Prof. Anton Zeilinger, and an article to Nature has already resulted from this. I believe that collaboration will continue long into the future on various topics of mutual interest. Finally, I have been working on complementary variables in theormodynamical systems, in collaboration with Dr. Beatrix Hiesmayr, from the Institute for Theoretical Physics. This I expect to be written up soon also in a form of a letter. I have also been having extensive and very useful discussions with Profs. Narnhofer and Thirring as well as Prof. Svozil from the Technical University in Vienna. I have attended a number of meetings during my stay, two in Italy, one in UK, one in Slovakia and several in Vienna and have been invited to give a number of talks on the subject of my research at the ESI.

I have had four visitors in total: Christian Lunkes, who is my PhD student from UK, and with whom I have written a paper during my stay; Dr. Marcelo Santos, with whom I am currently continuing collaboration; Caroline Rogers, also my student from London, with whom I am working on quantum Kolmogorov complexity and finalising a paper on it presently; and Mark Tame, with whom I am working on implementing quantum algorithms.

**Preprints contributed:** [1612], [1613], [1614],[1615]

### Boban Velickovic: Introduction to Descriptive Set Theory

**Course:** During my stay at the ESI I gave a course on *Descriptive Set Theory*. The goal of the course was to provide some background in the subject leading up to the most recent result in the study of Borel equivalence relations and classification problems. This is a very exciting subject connecting mathematical logic with ergodic theory, group representation theory, $C^*$-algebras, etc. A general classification problem is given to us by an action of a locally compact or more generally Polish group on a Polish space. We study the induced orbit equivalence relation and ask what kind of invariants can one have classifying objects in our space up to orbit equivalence. Descriptive set theory provides a framework and tools for studying this type of questions and in particular for analyzing the complexity of a given classification problem by comparing it to a certain 'benchmark' equivalence relation.

The first part of the course consisted of classical material on Borel and analytic sets in Polish spaces, their regularity properties, Choquet games, the Cantor-Bendixson analysis, the Kuratowski-Ulam theorem, tree representation of co-analytic sets, Kondo's uniformization theorem, etc. In the second part, we covered more advanced topics from effective descriptive set theory. Here, one uses ideas from computability theory to define a much finer hierarchy of Borel sets and projective sets and analyze their properties. In particular we studied Kleene's recursive ordinals, Gandy's basis theorem, hyperarithmetic sets. Due to the lack of time we did not cover all the topics, such as the Gandy- Harrington theorem and Silver's theorem on $\mathbf{\Pi}^1_1$-equivalence relations.

The attendance of the course varied from 8 to 12. In addition to several graduate students from the Kurt Gödel Center, there were 2 junior fellows (Viale and Shmileva) from the ESI and several senior mathematicians (Friedman, Goldstern, Mildenberger).

**Research:** During my stay at the ESI I have worked on the following projects:

- Shelah's conjecture about the existence of finite basis for uncountable linear orderings, i.e. a finite list of such orderings such that any other uncountable linear ordering contains an isomorphic copy of one of them. This is a part of a general program of classifying uncountable

structures. In 2003 J. Moore proved the consistency of Shelah's conjecture using rather strong large cardinal axioms. More recently, P. Larson, J. Moore and I have considerably reduced the assumptions used in the proof. It is still not clear if any strong axioms are required for this result.

- Dzamonja and I have worked on applications of the recent important results of Mitchell and Friedman concerning the forcing notions for adding a closed unbounded set to an inaccessible cardinal using finite conditions. We have some preliminary results and plan to continue working on this project in the future.

- A. Caicedo and I have obtained some interesting results on inner models of universes satisfying the Bounded Proper Forcing Axiom (BPFA). It is well known by the work of Gödel and Cohen that the size of the continuum is not decided by the usual axioms of set theory. It is therefore interesting to find additional natural axioms which would determine its cardinality. Caicedo and I use ideas from my paper *Forcing axioms and stationary sets.* **Adv. Math. 94 (1992), no. 2, 256–284** and some recent work of Moore to give, assuming BPFA, a coding of the reals by ordinals less than the second uncountable ordinal, $\aleph_2$, which shows that BPFA saturates the real line in the sense that any bigger universe having the same $\aleph_2$ and satisfying BPFA has the same reals. This paper is currently being typed and will be submitted to the ESI preprint service.

- I. Farah and I have worked on the problem of characterizing measure algebras. In the 1930s and 1940s Von Neumann and Maharam asked if certain algebraic properties characterize measure algebras. There is a related and stronger problem of Prikry if there is a finite basis for complete Boolean algebras satisfying the countable chain conditions (ccc). Two examples of such algebras are Borel sets module the ideals of Lebesgue null sets (measure algebra) and modulo the ideal of first category (Cohen algebra). These two algebras do not embed into each other, but interestingly the square of the former contains a copy of the latter. Farah and I obtained a general result about squares of ccc complete algebras and show that the Cohen algebra embeds into the square of any Maharam algebra and that consistenly it embeds into the cube of any nonatomic ccc complete Boolean algebra. A preliminary version of this paper has already been typed.

During my stay at the Schrödinger Institute I had the following visitors:

Yi Zhang, Sun Yat-sen University, Guangzhou, China, October 1 - 8
Menachem Kojman, Beer Sheva University, Beer Sheva, Israel, October 1-10
Mirna Dzamonja, East Anglia University, Norwich, UK, October 14-31
Grzegorz Plebanek, Wroclaw University, Wroclaw, Poland, October 25-28
Ilijas Farah, York University, Toronto, Canada, December 6-16

Zhang, Kojman, Plebanek and Farah were payed by the Schrödinger Institute and Dzamonja was payed by the Kurt Gödel Research Center for Mathematical Logic. Kojman, Plebanek and Farah gave lectures in the Schrödinger Instiute and Kojman, Dzamonja and Farah gave lectures at the Kurt Gödel Research Center. Zhang and Plebanek submitted papers to the ESI preprint server concerning work that has relations to their visit to the ESI:

-Tapani Hyttinen, Yi Zhang, *Several Mad Families and their Neighbors*

-Piotr Borodulin - Nadzieja, Grzegorz Plebanek, *On compactness of measures on Polish spaces*

**Collaboration with local mathematicians:** In addition to supervising my graduate student Matteo Viale who was a Junior Research Fellow at ESI for the same period, I have participated in the Logic Seminar at the Kurt Gödel Research Center for Mathematical Logic and have collaborated with Sy Friedman and Andres Caicedo. David Schrittesser, who is a gradute student at the Kurt Göodel Research Center has taken a reading course with me on *Forcing axioms and the continuum*. We intend to make notes of it which may be submitted to the ESI Lecture Notes Series. Schrittesser would like to continue working on his PhD thesis on the theory of forcing and its applications. We plan to make a co-mentorship agreement which would allow him to spend some time working with me in Paris on these topics.

I have also had contacts with the Database and Artificial Intelligence Group at the Computer Science Department at the Technical University of Vienna. I attended a *Workshop on Graph and Hypergraph Decompositions* at the Technical University from December 16 to 18, 2004.

**Preprints contributed:** [1527], [1562], [1600]

### Anton Wakolbinger: Stochastic Processes from Population Genetics

**Course:** Among the audience of my weekly ESI Lecture Course 'Stochastic Processes from Population Genetics' were Junior Research Fellows (Shmileva, Birkner, Angerer, Tutschka), graduate students (Haböck, Schneider, Ableitinger) and colleagues fom Vienna University (Bürger, Futschik, Krall).

Topics covered were:

- Transport of type proportions (Fisher-Wright diffusion)
- random genealogies (Kingman's coalescent),
- Infinite-alleles-model and Ewens sampling formula,
- the Donnelly-Kurtz lookdown construction of the Fleming-Viot model,
- the ancestral selection grapph,
- coupled gene trees and the ancestral recombination graph,
- Wright's island model and the structured coalescent
- diffusive clustering and diversity on large scales in the two-dimensional stepping-stone model.

The course web page is at http://www.esi.ac.at/activities/archive/Genetics-WS04.html.

**Research:** During my stay I worked on the following projects:

a) *Alpha-Branching and Beta-Coalescents* (with Matthias Birkner, Alison Etheridge, Martin Möhle, Jochen Blath, Marcella Capaldo and Jason Schweinsberg).

b) *Approximate sampling formulae under genetic hitchhiking* (with Peter Pfaffelhuber and Alison Etheridge).

c) *Random partitions in the Luria-Delbrück model* (with Wolfgang Angerer).

d) *Mathematical models for Muller's ratchet* (with Matthias Birkner and Alison Etheridge).

e) *Stepping stone models on 'general' islands* (with Ted Cox and Matthias Birkner).

All these projects concern research in stochastic processes, with background from population biology and genetics.

**Project a)** is on the interplay between continuous state branching processes and random genealogies (coalescents). The project had been initiated when three of us (Birkner, Möhle and I) participated in an ESI Workshop in December 2003, and was completed in November 2004 when three of us (Birkner, Etheridge and I) visited the ESI. The paper was submitted as ESI Preprint [1542] and accepted for publication in the Electronic Journal of Probability on Feb 04, 2005. The main result is that that the continuous-state branching processes for which the genealogy, suitably time-changed, can be described by an autonomous Markov process are precisely those arising from alpha-stable branching mechanisms, and that in this case the random ancestral partition is a time-changed Lambda-coalescent, where Lambda is a Beta-distribution. The related topics of Levy Processes and Lambda-Coalescents were subject of intensive discussions with Elena Shmileva (St.Petersburg/ESI), who gave an introductory review on these topics end of January in Prof. Schmidt's ESI seminar.

**Project b)** explores the genetic diversity at a neural locus close to a selective one after a so called selective sweep. (The latter means that a selectively advantageous allele, after entering into the population, went to fixation in a rather short time.) For a certain trade-off between selection strength an recombination rate it turns out that (though only with rather small probability) there can be non-singleton recombinant haplotypes in the sample. In a diffusion model for the evolution of type proportions we were able to compute the approximate distribution of the random partition of the sample with respect to identity by descent from the beginning of the sweep. This project experienced a breakthrough on the occasion of the ESI visits of my share guests Prof. Etheridge (in November 2004) and Dr. Pfaffelhuber (in January 2005). Both of them participated in the ESI workshop which I organized in November 2004. A manuscript is close to completion and will be submitted as an ESI preprint presumably in March 2005. In late January, I reported on the progress in this project in the Vienna ISDS Colloquium.

**Projects c), d) and e)** are described in more detal in the reports of the ESI Junior Research Fellows Dr.Angerer and Dr. Birkner. We plan to finish a manuscript on c) and to submit it as an ESI preprint this March. Project d), which was intensely discussed at ESI also with Don Dawson and Reinhard Bürger in November/December 2004, and project e), which was initiated during Ted Cox' ESI visit in December 2004, are more long-term.

On January 24, 2005 I gave a lecture 'Random genealogies, selective sweeps and neutral hitchhikers' in the ISDS Colloquium of Vienna University (invited by Prof. Bomze), and on January 25, 2005 I gave a 90 minutes talk 'Stochastic insertion-deletion processes and statistical sequence alignment in the ISDS Privatissimum Biostatistik.

I also had the pleasure to announce a number of seminar talks, given by Dr. Birkner, Dr. Angerer, Prof. Cox and Dr. Pfaffelhuber. Lectures of my share guests Prof. Dawson and Prof. Etheridge were given within the workshop on 'Stochastic processes from physics and biology', which I organized at the ESI from November 26-27, 2004. [cf. Workshops organized outside the main programs]

Here is the list, plus brief portraits, of my share guests:

Prof. Donald Dawson (School of Mathematics and Statistics, Carleton University, Ottawa) is one of the founders of the theory of measure-valued processes. Currently he is President of the

Bernoulli Society. We have a number of joint publications, one of which is ESI preprint 1393.
Prof. Alison Etheridge (Mathematics Department and Dept. of Statistics, University of Oxford) is a specialist on spatial population models, and has a long-standing collaboration with the theoretical biologist Nick Barton (Edinburgh). She was one of the medallion lecturers at the joint IMS and Bernoulli world congress 2004.
Prof. Ted Cox (Mathematics Department, University of Syracuse, N.Y.) has done groundbreaking work on interacting particle systems, coalescing random walks and the stepping stone model.
Dr. Peter Pfaffelhuber (Department of Biology, University of Munich) is a junior researcher, and works as a mathematician in the group of Wolfgang Stephan, who is a leading population genetist in Germany.

**Resumé:** I found the Schrödinger Institute a great place for doing research and interacting with other researchers, both junior and senior. The programs are rich, the atmosphere is friendly, and the administration is frictionless and efficient. Austria is to be congratulated for having a research institution like this.

**Preprints contributed:** [1542]

## Junior Research Fellows Program

Starting in 2004, the Senior Research Fellows Program was complemented by a Junior Research Fellows Program, funded by the Austrian government, to provide support for PhD students and young post-docs to participate in the scientific activities of the Institute and to collaborate with its visitors and members of the local scientific community.

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

**Status of applications:**

1st deadline: February 15th, 2004
Number of applications: 40
Number of accepted applicants: 18
Number of accepted months: 48/04, 19/05

2nd deadline: May 31st, 2004
Number of applications: 38
Number of accepted applicants: 9
Number of accepted months: 8/04, 18/05, 2/06

3rd deadline: November 15th, 2004
Number of applications: 65
Number of accepted applicants: 7
Number of accepted months: 20/05

| name | gender | duration | nationality |
|---|---|---|---|
| Wolfgang Angerer | male | 01/11 - 31/12 | Austria |
| Jessica Barrett | female | 01/10 - 31/03/05 | Great Britain |
| Matthias Birkner | male | 01/11 - 31/12 | Germany |
| Jeremy Clark | male | 29/09 - 02/12 | USA |
| Ionas Erb | male | 01/09 - 30/11 | Germany |
| Borislav Gajic | male | 02/05 - 31/07 | Serbia |
| Alessandro Giuliani | male | 01/09 - 31/10 | Italy |
| Marcela Hanzer | female | 01/10 - 31/01/05 | Croatia |
| Bianca Mladek | female | 01/05 - 31/10 | Austria |
| Ari Pakman | male | 26/04 - 26/06 | Argentina |
| Milena Radnovic | female | 02/05 - 31/07 | Serbia |
| Karl Georg Schlesinger | male | 01/05 - 31/07 | Germany |
| Jeff Selden | male | 14/09 - 15/12 | USA |
| Alexandre Stefanov | male | 30/08 - 31/01/05 | Bulgaria |
| Jesper Tidblom | male | 18/10 - 18/12 | Sweden |
| Christian Tutschka | male | 01/07 - 31/12 | Austria |
| Matteo Viale | male | 01/10 - 31/12 | Italy |
| Vojtěch Žadník | male | 06/09 - 31/12 | Czech Republic |

## Visitors outside the main programs

Visitors to ESI not associated with any of the main programs and workshops in 2004, but related to previous ones, have so far contributed the following preprints: [1434], [1435], [1440], [1445], [1446], [1452], [1453], [1454], [1455], [1465], [1472], [1476], [1482], [1500], [1515], [1520], [1521], [1522], [1523], [1524]

This list includes preprints contributed by the Senior Research Fellows and their collaborators.

**Guests of A. Čap:** Simon Gindikin, Rod Gover, Vladimir Souček

**Guests of K. Schmidt:** Sarah Bailey, Vitaly Bergelson, Louis Block, Guy Cohen, Danijela Damjanovic, Szasz Domokos, Patrick Foulon, Yossi Moshe, Athanase Papadopoulos, Yakov Pesin, Karl Petersen, Elena Shmileva, Michael Shub, Varju Tamas, Wolfgang Wöss

**Guests of J. Schwermer:** Marc Burger, Karel Dekimpe, Alessandra Iozzi, Jens Carsten Jantzen, Hiroki Kodama, Stephen Kudla, Arvind Nair, Jürgen Rohlfs, Stefan Schraml

**Guests of J. Yngvason:** Thomas Kappeler, Ari Laptev, Giovanni Rotondaro, Bert Schroer, Eric Sharpe, Giovanni Sparano, Gaetano Vilasi

**Guests of Senior Research Fellows:**

**Guests of P. van Nieuwenhuizen:** Robert Wimmer

**Guests of W. Ballmann:** Christian Bär

**Guests of J. Fuchs:** Jens Fjelstad

**Guests of M. Salmhofer:** Christoph Husemann, Walter Pedra

**Guests of V. Vedral:** Caroline Rogers, Mark Tame, Marcelo Santos

**Guests of B. Velickovic:** Ilijas Farah, Menachem Kojman, Grzegorz Plebanek, Yi Zhang

**Guests of A. Wakolbinger:** Ted Cox, Donald Dawson, Alison Etheridge

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## All visitors in 2004

The following codes indicate the association of visitors with particular programs:

ABK = Singularity Formation in Nonlinear Evolution Equations
ACM = Advisory Comittee Meeting
BCS = Geometric and analytic problems related to Cartan connections
BSC = Workshop on Penrose Inequalities
CAP = Guest of Prof. Čap
FAD = Ludwig Faddeev Conference
FHK = Tensor Categories in Mathematics and Physics
GRS = String Theory in Curved Backgrounds and Boundary Conformal Field Theory
JF = Junior Fellow
KNV = Gravity in Two Dimensions (program of 2003)
LIE = Seminar Sophus Lie
MAK = Summer School and Workshop on Nonlinear Wave Equations
POD = Workshop on Stochastic and Deterministic Dynamics in Equilibrium and Nonequilibrium Systems
SCH = Guest of Prof. Schmidt
SCHW = Guest of Prof. Schwermer
SF = Senior Research Fellow
SFS = Senior Research Fellow Share
SY = Many-Body Quantum Theory
THI = Guest of Prof. Thirring
YNG = Guest of Prof. Yngvason

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Li Haisheng, Rutgers University; 23.06.2004 - 05.07.2004, FHK
Lieb Elliott, University of Princeton; 02.03.2004 - 16.03.2004, ACM
Loew Hans G., University of Vienna; 25.08.2004 - 28.08.2004, POD
Loll Renate, Spinoza Institute; 25.11.2004 - 28.11.2004, YNG
Losik Mark V., Saratov State University, Department of Mathematics ; 01.08.2004 - 30.09.2004, MI
Loss Michael, Georgia Tech. School of Mathematics; 14.12.2004 - 20.12.2004, SY
Louis Jan, II. Institut für Theoretische Physik ; 25.11.2004 - 28.11.2004, YNG
Lucente Sandra, Universita di Bari; 07.07.2004 - 13.07.2004, MAK
Luchinsky Dmitry G., Lancaster University; 24.08.2004 - 28.08.2004, POD
Lyakhovskaya Anna, MIT; 20.06.2004 - 03.07.2004, FHK
Lyubashenko Volodymyr, Inst. of Mathematics NASU; 18.06.2004 - 27.06.2004, FHK
MacKay Niall, University of York; 10.06.2004 - 16.06.2004, GRS
Madore John, Université de Paris Sud, Laboratoire de Physique Theorique, et Hautes Energies; 27.05. 2004 - 17.06.2004, GRS
Magnen Jacques, Ecole Polytechnique, CNRS; 06.09.2004 - 10.09.2004, SY
Maillet Jean Michel, ENS Lyon and CNRS; 20.03.2004 - 26.03.2004, FAD
Malec Eduard, Jagiellonian University, Institute of Physics; 26.07.2004 - 08.08.2004, BSC
Markham Damian, University of Tokyo; 15.11.2004 - 16.11.2004, SFS
Mars Marc, Faculty of Physics, University of Salamanca; 24.07.2004 - 07.08.2004, BSC
Martin-Garcia Jose M., Instituto de Matematicas y Fisica Fundamental; 24.07.2004 - 17.08.2004, ABK
Masbaum Gregor, Inst. de Mathematiques de Jussieu; 18.06.2004 - 05.07.2004, FHK
Mason Geoffrey, University of California; 26.06.2004 - 04.07.2004, FHK
Mastropietro Vieri, Universitá di Roma 'Tor Vergata'; 04.09.2004 - 11.09.2004, SY; 30.11.2004 - 05.12. 2004, SY
Mátyás László, Université Libre de Bruxelles; 25.08.2004 - 28.08.2004, POD
Meinhart Max, TU Wien; 25.08.2004 - 28.08.2004, POD

Metcalfe Jason, Georgia Inst. of Technology; 06.07.2004 - 15.07.2004, MAK
Metzner Walter, MPI FKF Stuttgart; 06.09.2004 - 10.09.2004, SY; 19.10.2004 - 22.10.2004, SY
Meurman Arne, University of Lund; 19.06.2004 - 04.07.2004, FHK
Milas Antun, SUNY; 21.06.2004 - 04.07.2004, FHK
Mittag Emil, Universität Hamburg; 24.08.2004 - 29.08.2004, POD
Miwa Tetsuji, Department of Mathematics; 22.03.2004 - 26.03.2004, FAD
Mladek Bianca, Inst. für Theoretische Physik; 01.05.2004 - 31.10.2004, JF
Mohrdieck Stephan, Math. Institut; 20.06.2004 - 29.06.2004, FHK
Moncrief Vincent, Yale University, Physics Department; 16.07.2004 - 01.08.2004, ABK
Morimoto Tohru, Nara Women's University; 05.01.2004 - 12.01.2004, BCS
Morriss Gary, University of New South Wales; 25.08.2004 - 28.08.2004, POD
Mück Matthias, Johannes Gutenberg Universität; 27.07.2004 - 30.07.2004, ABK
Müger Michael, University of Amsterdam; 12.06.2004 - 27.06.2004, FHK
Muic Goran, University of Zagreb; 05.12.2004 - 10.12.2004, SCHW
Mukamel David, The Weizman Institute; 24.08.2004 - 29.08.2004, POD
Mukamel Shaul, Univ. of California; 24.08.2004 - 29.08.2004, POD
Nachtergaele Bruno, University of California, Dept. of Mathematics; 06.09.2004 - 11.09.2004, SY; 24.10. 2004 - 14.11.2004, SY; 29.11.2004 - 14.12.2004, SY
Nagao Takeyuki, University of Tokyo; 02.03.2004 - 04.03.2004, YNG
Nagatomo Kiyokazu, Osaka University; 21.06.2004 - 28.06.2004, FHK
Nagy Paul-Andi, Humboldt-Universität Berlin; 01.04.2004 - 07.04.2004, BCS
Narnhofer Heide, Inst. f. theoretische Physik; 25.08.2004 - 28.08.2004, POD
Neretin Yurii A., ITEP (Institute of Theoretical and, Experimental Physics) Math. Physics Group; 15.11.2003 - 15.01.2004, MI
Niemi Antti, Uppsala University, Dept. of Theoretical Physics; 20.03.2004 - 26.03.2004, FAD
Nilles Hans Peter, Physikalisches Institut; 25.11.2004 - 28.11.2004, YNG
Nurowski Pawel, Warsaw University, Dept. of Math. Methods in Physics; 06.01.2004 - 17.01.2004, BCS
Odzijewicz Anatol, University of Bialystoic, Institute of Theoretical Physics; 28.04.2004 - 13.05.2004, GRS
Ocneanu Adrian, Pennsylvania State University; 13.06.2004 - 04.07.2004, FHK
Olive David, University of Wales Swansea; 22.11.2004 - 29.11.2004, YNG
O'Murchadha Niall, University College Cork, Physics Department; 26.07.2004 - 08.08.2004, BSC
Orsted Bent, IMADA, SDU; 09.01.2004 - 18.01.2004, BCS
Ostrik Victor, Institute for Advanced Study; 20.06.2004 - 04.07.2004, FHK
Pakman Ari, Racah Institute, Hebrew University; 28.04.2004 - 28.06.2004, JF
Pakuliak Stanislav, Bogoliubov Lab. Theor. Phys., JINR; 22.03.2004 - 26.03.2004, FAD
Papadopoulos Athanase, Universite Louis Pasteur; 22.09.2004 - 28.09.2004, SCH
Pareigis Bodo, University of Munich; 20.06.2004 - 27.06.2004, FHK
Pawelczyk Jacek, Institute of Theoretical Physics; 03.05.2004 - 07.05.2004, GRS; 31.05.2004 - 10.06.2004, GRS
Pearce Paul A., University of Melbourne; 06.06.2004 - 22.06.2004, GRS
Petersen Karl, University of North Carolina, Dept. of Math.; 05.05.2004 - 14.06.2004, SCH
Pfaffelhuber Peter, Zoologisches Institut, LMU München; 25.11.2004 - 28.11.2004, SFS
Pfeiffer Hendryk, University of Cambridge; 20.06.2004 - 29.06.2004, FHK
Pi So-Young, Boston University; 25.03.2004 - 29.03.2004, FAD
Pinto Paulo Jorge, Inst. Superior Tecnico; 14.06.2004 - 23.06.2004, FHK
Plebanek Grzegorz, Inst. of Mathematics; 25.10.2004 - 28.10.2004, SFS

Pokorski Stefan, Institute for Theoretical Physics; 25.11.2004 - 28.11.2004, YNG
Polyakov Alexandre, Princeton University; 23.03.2004 - 25.03.2004, FAD
Primc Mirko, Department of Mathematics; 21.06.2004 - 04.07.2004, FHK; 05.12.2004 - 12.12.2004, SCHW
Quella Thomas, King's College London; 28.05.2004 - 21.06.2004, GRS
Radnović Milena, Mathematical Institute Sanu ; 02.05.2004 - 31.07.2004, JF
Radons Günter, TU Chemnitz; 24.08.2004 - 28.08.2004, POD
Radovanović Voja, Faculty of Physics; 02.06.2004 - 01.07.2004, FHK
Reames Matthew, University of Maryland; 25.08.2004 - 28.08.2004, POD
Recknagel Andreas, King's College, Department of Mathematics; 02.04.2004 - 24.04.2004, GRS; 01.05. 2004 - 27.05.2004, GRS; 02.06.2004 - 24.06.2004, GRS
Reffert Susanne, Humboldt Universität, zu Berlin; 14.07.2004 - 18.07.2004, FHK
Rendall Alan, Max-Planck-Institut für Astrophysik; 04.07.2004 - 16.07.2004, ABK
Reshetikhin Nicolai, Department of Mathematics; 22.03.2004 - 28.03.2004, FAD
Retakh Alexander, MIT; 21.06.2004 - 04.07.2004, FHK
Rey Soo-Jong, Seoul National University, School of Physics; 13.06.2004 - 20.06.2004, GRS
Ribault Sylvain, King's College London; 07.06.2004 - 21.06.2004, GRS
Ringström Hans, Max-Planck-Institut für Gravitationsphysik; 26.07.2004 - 14.08.2004, ABK
Rogers Caroline, University of Warwick; 29.11.2004 - 13.12.2004, SFS
Roggenkamp Daniel, ETH Zürich; 27.04.2004 - 15.05.2004, GRS
Rohe Daniel, MPI-FKF Stuttgart; 06.09.2004 - 10.09.2004, SY; 19.10.2004 - 22.10.2004, SY
Rohlfs Jürgen, Universität Eichstätt; 13.10.2003 - 13.02.2004, SF; 21.06.2004 - 26.06.2004, SCHW; 05.12.2004 - 09.12.2004, SCHW
Rondoni Lamberto, Politecnico di Torino; 24.08.2004 - 29.08.2004, POD
Rosch Achim, Universität Köln; 06.09.2004 - 12.09.2004, SY
Rosellen Markus, University of Stockholm; 19.06.2004 - 04.07.2004, FHK
Giovanni Rotondaro, Dept. of Math. and Applications; 08.03.2004 - 16.03.2004, YNG
Runkel Ingo, Inst. f. Physik; 04.05.2004 - 11.05.2004, GRS; 08.06.2004 - 14.06.2004, GRS; 21.06.2004 - 06.07.2004, FHK
Salmhofer Manfred, Universität Leipzig; 02.09.2004 - 05.12.2004, SF
Sato Nobuya, Rikkyo University; 27.06.2004 - 02.07.2004, FHK
Schimmrigk Rolf, Kennesaw State University; 05.05.2004 - 14.05.2004, GRS
Schlesinger Karl-Georg, ESI; 01.05.2004 - 31.07.2004, JF
Schlichenmaier Martin, University of Luxembourg; 15.06.2004 - 24.06.2004, FHK
Schmalz Gerd, Universität Bonn, Mathematisches Institut; 08.02.2004 - 14.02.2004, BCS
Schnee Kai, ESI; 24.03.2004 - 24.03.2004, EU
Schönhammer Kurt, Inst. f. Theoretische Physik; 07.09.2004 - 17.09.2004, SY
Schomerus Volker, SPhT CEA/Saclay ; 26.04.2004 - 26.06.2004, GRS
Schrader Robert, Freie Universität Berlin, Institut für Theoretische Physik; 22.03.2004 - 28.03.2004, FAD
Schraml Stefan, Max-Planck-Institut f. Physik; 15.12.2004 - 22.12.2004, SCHW
Schroer Bert, CBPF Rio de Janeiro; 19.06.2004 - 28.06.2004, YNG
Schupp Peter, Intl. Univ. Bremen; 15.05.2004 - 28.05.2004, GRS
Schwachhöfer Lorenz, Universität Dortmund, Mathematisches Institut; 14.03.2004 - 27.03.2004, BCS
Schweigert Christoph, Universität Hamburg; 16.06.2004 - 01.07.2004, FHK
Schwimmers Adam, Weizmann Institute, Physics Dept.; 24.05.2004 - 31.05.2004, GRS
Seiler Ruedi, Technische Universität Berlin; 22.03.2004 - 25.03.2004, FAD; 01.12.2004 - 05.12.2004, SY
Seiringer Robert, Department of Physics; 05.09.2004 - 12.09.2004, SY; 24.10.2004 - 31.10.2004, SY
Selberg Sigmund, Johns Hopkins University; 06.07.2004 - 15.07.2004, MAK

Selden Jeffrey, ESI; 13.09.2004 - 14.12.2004, JF
Semenov-Tian-Shansky Michael, Université de Bourgogne; 21.03.2004 - 28.03.2004, FAD
Semmelmann Uwe, Universität Hamburg, FB Mathematik; 26.02.2004 - 05.03.2004, BCS
Sevick Edie, The Australian National University; 25.08.2004 - 28.08.2004, POD
Sharpe Eric, University of Utah; 25.11.2004 - 30.11.2004, YNG
Sigal Israel Michael, University of Toronto, Dept. of Mathematics; 05.07.2004 - 31.08.2004, ABK
Silhan Josef, University of Auckland; 05.01.2004 - 15.01.2004, BCS
Simon Károly, University of Budapest, Institute of Mathematics Technical; 20.06.2004 - 29.06.2004; 06.10.2004 - 12.10.2004, SCH
Simon Walter, Fisica Teorica; 26.07.2004 - 08.08.2004, BSC
Singhof Wilhelm, Universität Düsseldorf; 05.12.2004 - 09.12.2004, SCHW
Shatashvili Samson, Trinity College Dublin; 21.03.2004 - 26.03.2004, FAD
Slavnov Andrey, Steklov Mathematical Institute; 21.03.2004 - 26.03.2004, FAD
Slovák Jan, Masaryk University, Department of Algebra and Geometry; 07.01.2004 - 30.01.2004, BCS
Smid Dalibor, Charles University of Prague; 27.01.2004 - 15.04.2004, BCS
Smirnov Fedor, LPTHE; 21.03.2004 - 26.03.2004, FAD
Somberg Petr, Charles University, Institute of Mathematic; 27.01.2004 - 15.02.2004, BCS
Sorba Paul, LAPTH - CNRS; 07.06.2004 - 13.06.2004, GRS
Stroppel Catharina, University of Glasgow; 27.06.2004 - 03.07.2004, FHK
Suszek Rafal Roman, University of Warsaw; 06.06.2004 - 21.06.2004, GRS
Souček Vladimir, Charles University, Faculty of Mathematics and Physics, Mathematical Institute; 27.01.2004 - 03.02.2004, BCS; 08.02.2004 - 13.02.2004, BCS; 22.02.2004 - 02.03.2004, BCS; 21.03.2004 - 09.04.2004, BCS; 19.10.2004 - 20.10.2004, CAP
Sparano Giovanni, Universitá di Salerno, DMI; 08.03.2004 - 16.03.2004, YNG
Stanton Robert, Ohio State University; 22.03.2004 - 07.04.2004, BCS
Steinacker Harold, Ludwig-Maximiliansuniversität München, Institut f. Theoretische Physik; 09.05.2004 - 15.05.2004, GRS; 30.05.2004 - 04.06.2004, GRS
Sternheimer Daniel, Université de Bourgogne, CNRS at Physique Mathématique; 20.03.2004 - 26.03.2004, FAD
Strasburger Alexander, Warsaw Agricultural University; 08.01.2004 - 10.01.2004, LIE
Struwe Michael, ETH Zürich; 08.08.2004 - 11.08.2004, ABK
Styrkas Konstantin, USC, Los Angeles; 23.06.2004 - 03.07.2004, FHK
Szász Domokos, Budapest University of Technology; 21.11.2004 - 30.11.2004, SCH
Szczesny Matthew Maciej, University of Pennsylvania; 16.06.2004 - 30.06.2004, FHK
Szendroi Balázs, Universiteit Utrecht; 02.05.2004 - 09.05.2004, GRS
Szenes Andras, BME Institute of Mathematics, Department of Geometry; 02.05.2004 - 09.05.2004, GRS
Szlachányi Kornél, Inst. for Particle and Nuclear Physics; 21.06.2004 - 04.07.2004, FHK
Tabor Zbislaw, Department of Biophysics; 09.08.2004 - 13.08.2004, ABK
Tadic Marko, University of Zagreb; 05.12.2004 - 12.12.2004, SCHW
Tafel Jacek, University of Warsaw, Institute of Theoretical Physics; 13.04.2004 - 27.04.2004, BCS
Takhtajan Leon, SUNY at Stony Brook, Department of Mathematics; 22.03.2004 - 27.03.2004, FAD
Talkner Peter, Univ. Augsburg; 24.08.2004 - 29.08.2004, POD
Tame Mark Simon, Queen's University Belfast; 06.12.2004 - 11.12.2004, SFS
Taniguchi Tooru, University of New South Wales; 25.08.2004 - 28.08.2004, POD
Tarasov Vitaly, IUPUI Indianapolis; 22.03.2004 - 27.03.2004, FAD
Tarulli Mirko, Universita di Pisa; 06.07.2004 - 14.07.2004, MAK
Teofanov Nenad, Univ. Novi Sad, Dept. of Mathematics and Informatics, Faculty of Sciences ; 16.11.2004

- 26.11.2004, JF
Teschner Jörg, Freie Univ. Berlin; 06.06.2004 - 21.06.2004, GRS
Theisen Stefan, Albert-Einstein-Institut; 13.05.2004 - 02.06.2004, GRS
Tidblom Jesper, Inst. of Mathematics; 18.10.2004 - 18.12.2004, JF
Toledano Laredo Valerio, Inst. de Mathematiques de Jussieu; 19.06.2004 - 04.07.2004, FHK
Travaglia Marcos, University of Mainz; 01.12.2004 - 14.12.2004, SY
Tremblay André-Marie, University of Sherbrooke; 05.09.2004 - 11.09.2004, SY
Tsuchyia Akihiro, Nagoya University; 27.06.2004 - 02.07.2004, FHK
Tuba Imre, Virginia Tech; 17.06.2004 - 04.07.2004, FHK
Tutschka Christian, Inst. f. Theor. Physik, TU Wien; 01.07.2004 - 31.12.2004, JF
Ugalde William, Purdue University; 12.03.2004 - 25.03.2004, BCS
Van Beijeren Henk, Utrecht University; 24.08.2004 - 28.08.2004, POD
Van Nieuwenhuizen Peter, State University of New York; 04.01.2004 - 31.01.2004, SF
Van Zon Ramses, Rockefeller University; 22.08.2004 - 27.08.2004, POD
Varghese Mathai, University of Adelaide; 26.05.2004 - 30.05.2004, GRS
Varjú Tamaś, Technical University Budapest; 20.01.2004 - 24.01.2004, SCH
Vecsernyés Péter, Research Institute for Perticle and Nuclear Physics, Dept. of Mathematical Physics ; 22.06.2004 - 04.07.2004, FHK
Vedral Vlatko, School of Physics and Astronomy; 10.09.2004 - 31.12.2004, SF
Velazquez Juan, Universidad Complutense; 18.07.2004 - 25.07.2004, ABK
Velickovic Boban, UFR de Mathematiques, Universite de Paris 7; 01.10.2004 - 31.12.2004, SF
Venkov Alexei, Mathematical Insitute; 20.03.2004 - 25.03.2004, FAD
Viale Matteo, Universite de Paris 7; 04.10.2004 - 31.12.2004, JF
Villanueva Alfredo, University of Iowa; 13.03.2004 - 21.03.2004, BCS
Vilasi Gaetano, Universitá di Salerno, Dipartimento di Fisiche "E.R. Caianiello"; 08.03.2004 - 17.03.2004, YNG
Visciglia Nicola, Universita di Pisa; 06.07.2004 - 15.07.2004, MAK
Volkov Alexandre, TENA, VUB and, Steklov Mathematical Institut; 21.03.2004 - 26.03.2004, FAD
Wasserman Arthur, University of Michigan; 10.07.2004 - 14.07.2004, ABK
Watts Gerard, King's College; 07.06.2004 - 19.06.2004, GRS
Wegner Franz, Universität Heidelberg, Institut für Theoretische Physik; 05.09.2004 - 18.09.2004, SY
Weingart Gregor, Friedrich-Wilhelms, Universität; 25.02.2004 - 05.03.2004, BCS
Weiss Julian, University of Warwick; 06.07.2004 - 14.07.2004, MAK
Wendland Katrin, University of Warwick; 25.04.2004 - 13.05.2004, GRS
Wendt Robert, University of Toronto; 21.06.2004 - 04.07.2004, FHK
Wess Julius, Universität München; 08.06.2004 - 20.06.2004, GRS
West Peter, King's College, Maths Department; 19.04.2004 - 30.04.2004, GRS; 14.06.2004 - 29.06.2004, GRS
Wetterich Christof, Institut f. Theoretische Physik; 08.10.2004 - 12.10.2004, SY
Williams J.F., University of Leiden; 02.08.2004 - 15.08.2004, ABK
Williams Stephen, Australian National University; 25.08.2004 - 28.08.2004, POD
Wimmer Robert, University Hannover; 05.01.2004 - 20.01.2004, SFS
Winter Anita, Mathematisches Institut; 25.11.2004 - 28.11.2004, SFS
Woess Wolfgang, TU Graz; 17.05.2004 - 19.05.2004, SCH
Wulkenhaar Raimar, Max-Planck-Institute for Mathematics in the Sciences; 26.06.2004 - 02.07.2004, GRS; 31.07.2004 - 07.08.2004, GRS; 24.11.2004 - 03.12.2004, GRS
Yamaguchi Keizo, Hokkaido University, Faculty of Science, Dept. of Mathematics; 09.02.2004 - 21.02.

2004, BCS
Yang Hongliu, Chemnitz University of Technology; 25.08.2004 - 28.08.2004, POD
Yang Paul, Princeton University; 25.02.2004 - 07.03.2004, BCS
Yau Kwan Kiu, State University of New York; 14.06.2004 - 28.06.2004, FHK
Yokura Shoji, University of Kagoshima, Faculty of Science, Dept. of Mathematics and Computer Science; 09.08.2004 - 23.08.2004, MI
Zabey Emmanuel, Univ. de Geneve; 24.08.2004 - 29.08.2004, POD
Zádník Vojtěch, Masaryk University; 31.03.2004 - 02.04.2004, BCS
Zagrebnov Valentin, Université Aix-Marseille II; 28.11.2004 - 11.12.2004, SY
Zaitsev Dmitri, Trinity College Dublin; 19.03.2004 - 28.03.2004, BCS
Zappacosta Stefano, University of L'Aquila; 06.07.2004 - 15.07.2004, MAK
Zhang Yi, Sun Yat-Sen Univerity; 01.10.2004 - 09.10.2004, SFS
Zhislin Grigorii, Radio-Physical Research Institute; 17.09.2004 - 18.10.2004, SY
Zirnbauer Martin R., Universität Köln, Institut für Theoretische Physik; 06.09.2004 - 11.09.2004, SY
Zito Pasquale Anthony, Universita di Roma 'Tor Vergata'; 21.06.2004 - 04.07.2004, FHK
Zunino Marco, Aarhus University; 16.06.2004 - 28.06.2004, FHK

## List of seminars and colloquia outside of conferences

2004 01 08, T. Morimoto: 'A general criterion for the existence of a Cartan connection and its application to sub-Riemannian structures'
2004 01 13, M. Cowling: 'The Cayley transform and uniformly bounded representations'
2004 01 14, P. Nurowski: 'G2 Cartan connection associated with equation z'=F(x,y,y',y",z)'
2004 01 16, B. Ørsted: 'A logarithmic Sobolev inequality in CR geometry'
2004 01 19, P. Raith: 'Multifraktale Dimensionen für invariante Teilmengen von stückweise monotonen Abbildungen'
2004 01 22, S. Kudla: 'An arithmetic theta lift'
2004 01 26, K. Schmidt: 'Quotients of $l^\infty$, toral automorphisms und beta-shifts'
2004 01 28, M. Eastwood: 'Higher symmetries of the Laplacian'
2004 01 30, D. Fox: 'Contact Projective Structures'
2004 02 05, B. Doubrov: 'On locally homogeneous curves in homogeneous spaces'
2004 02 11, P. Julg: 'From C*-algebras to complexes on flag manifolds'
2004 02 12, G. Schmalz: 'Non-linearizable CR automorphisms and shear-invariant second order ODE'
2004 02 13, K. Yamaguchi: 'Characterization of Hermitian symmetric spaces by fundamental forms'
2004 02 18, B. Doubrov: 'Cartan geometries associated with differential equations'
2004 02 26, O. Biquard: 'Quaternionic Kaehler metrics and their boundaries'
2004 03 01, M. Barberis: 'Geometric structures on Lie groups'
2004 03 02, A. Fino: 'KT and HKT geometry'
2004 03 02, M. Gursky: 'A fully nonlinear equation in conformal geometry and some applications'
2004 03 03, A. Chang: 'Q-curvature and renormalized volume'
2004 03 04, G. Weingart: 'Classification of Cartan geometries and spectral sequences'
2004 03 04, P. Yang: 'On a notion of minimal surface on CR geometry'
2004 03 10, T. Bailey: 'Radon transforms and Fourier transforms'
2004 03 11, D. Duchemin: 'Quaternionic contact structures in dimension 7'
2004 03 12, E. Lieb: 'Bose Einstein phase transition in an optical lattice model'
2004 03 12, W. Ballmann: 'On the spectrum of Dirac operators'
2004 03 17, K. Hirachi: 'Volume renormalization of strictly pseudoconvex domains'

2004 03 18, A. Iozzi: 'Bounded cohomology and maximal representations of surface groups'
2004 03 18, W. Ugalde: 'A construction of critical GJMS operators using Wodzicki's residue'
2004 03 19, D. Hong: 'Spectra of Higher Spin Operators on Spin 1/2 and Spin 3/2 fields'
2004 03 19, M. Burger: 'Some remarks on the role of non_positive curvature in group theory'
2004 03 22, W. Ballmann: 'Geodesic flows on simplicial complexes and applications'
2004 03 24, L. Schwachhöfer: 'Special symplectic connections'
2004 03 25, D. Zaitsev: 'Lie group structures on groups of CR automorphisms'
2004 03 29, P. Raith: 'When only one of two species survives, but one doesn't know which one'
2004 03 30, O. Hijazi: 'Extrinsic Spin Geometry and Applications'
2004 03 31, T. Branson: 'Detour complexes, half-torsion, and generalizations of the Q-curvature'
2004 04 01, R. Graham: 'Jet isomorphisms in conformal geometry'
2004 04 02, R. Stanton: 'Complex methods for real symmetric spaces'
2004 04 05, P. Nagy: 'Nearly Kähler manifolds with symmetries'
2004 04 06, F. Leitner: 'Twistor spinors with zeros in Lorentzian geometry'
2004 04 06, K. Galicki: 'Transverse Fano Structures and Einstein Metrics on Exotic Spheres'
2004 04 07, V. Soucek: 'Analogues of the Dolbeault complex in several Clifford variables'
2004 04 19, P. Foulon: 'Cocycles and Anosov flows'
2004 04 28, A. Nair: 'Introduction to Shimura-Varieties I'
2004 04 30, J. Fuchs: 'Conformal Field Theory'
2004 05 05, J. Schwermer: 'Galois cohomology and cycles on arithmetically defined manifolds'
2004 05 10, K. Petersen: 'Some joint symbolic dynamics- shifts and adic transformations'
2004 05 13, E. Scheidegger: 'Introduction to the topological vertex II'
2004 05 17, W. Woess: 'Random walks on lamplighter groups'
2004 05 18, K. Schlesinger: 'Symmetries in String Theory: An approach via universal algebraic symmetries'
2004 05 18, S. Theisen: 'SYM Strings and twistors I, II'
2004 05 24, V. Losert: 'Coboundaries and measure-preserving actions of nilpotent and solvable groups'
2004 05 25, A. Pakman: 'D-branes in noncompact backgrounds'
2004 05 26, A. Nair: 'On the cohomology of some noncompact locally symmetric spaces'
2004 05 27, K. Petersen: 'Coding and combinatorics of the Pascal adic'
2004 06 02, A. Carey: 'Local Index Theorem'
2004 06 03, V. Schomerus: 'Introduction to non-rational CFT'
2004 06 15, S. Gindikin: 'Complex geometry of real symmetric spaces'
2004 06 16, A. Nair: 'Lefschetz property for arithmetic ball quotients I'
2004 06 18, A. Fialowski: 'Global Deformations of the Virasoro algebra'
2004 06 18, I. Tuba: 'Classifying braided semisimple tensor categories'
2004 06 22, M. Radnovic: 'Poncelet's theorem and elliptic billiards'
2004 06 23, A. Nair: 'Lefschetz property for arithmetic ball quotients II'
2004 06 23, B. Gajic: 'Integration of Euler-Poisson equations using algebro-geometric methods'
2004 06 24, K. Simon: 'The dimension of graph directed attractors with overlaps on the line, with an application to a problem in fractal image recognition.'
2004 06 30, B. Mladek: 'Thermodynamically self-consistent liquid state theories for systems with bounded potentials'
2004 07 06, S. Klainerman: 'On the causal structure in General Relativity I + II'
2004 07 12, M. Dafermos: 'A proof of Price's law for the collapse of a self-gravitating scalar field'
2004 07 13, I. Sigal: 'Soliton dynamics in nonlinear Schrödinger equation'
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