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

Boltzmanngasse 9
A-1090 Wien, Austria

Scientific Report for the Year 1997

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ERWIN SCHRÖDINGER INTERNATIONAL INSTITUTE OF MATHEMATICAL PHYSICS, SCIENTIFIC REPORT FOR THE YEAR 1997

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General remarks

In the year 1997 ESI was host to 293 visitors. There were 106 preprints contributed to the preprint series (116 till beginning of February), some of them still belong to programs from 1996, and 162 seminar talks or ESI-Colloquia were given. Three conferences were organized in Vienna:

(1) Conference in ergodic theory, geometry and arithmetic. This was part of the program on ergodic theory and will be reported on there.
(2) Formal power series and algebraic combinatorics 97
(3) Workshop in local quantum physics. This was part of the program on local quantum physics and details are geven in the report on the program.

ESI took part in the organization of one conferences abroad, 'The 18th Winter school on geometry and physics', January 10–17, 1998, in Srni, a small village in the Bohemian forest, Czech republic.

ESI has spent AS 3,78 Mio for science which was supplemented by AS 1.12 Mio of foreign support; AS 5,92 Mio were spent for administrative costs including some open bills for the adapting the new premises.

Winter School in Geometry and Physics

The traditional winter school in geometry and physics which takes places for one week each January since 1980 in a picturesque village in the Czech parts of the Bohemian mountains is a joint enterprise of the Czech society of mathematicians and physicists and ESI, from 1994 onwards. Usually there are proceedings, which are published as a supplement of the 'Rendiconti Matematici di Palermo'.

In this year, the 17th Winter school on Geometry and Physics took place in the week January 11–18, 1997. ESI has contributed AS 10.000.– The former conferences with ESI-participation are published in the proceedings volumes:

The proceedings of the Winter school 'Geometry and Physics', Srní, January 1994. Suppl. Rend. Circ. Mat. Palermo, II. Ser. **39** (1996), 9–148
Contents:

The proceedings of the 15th Winter school 'Geometry and Physics', Srní, January 14–21, 1995. Suppl. Rend. Circ. Mat. Palermo, II. Ser. **43** (1996), 9–228
Contents:

The proceedings of the 16th Winter school 'Geometry and Physics', Srní, January 13–20, 1996.
Suppl. Rend. Circ. Mat. Palermo, II. Ser. **46** (1997), 9–176
Contents:

Conference: Formal power series and algebraic combinatorics 97

The 9th conference of this series of organized by Christian Krattenthaler at the University of Vienna, July 14–18, 1997. ESI has contributed 50.000.- to this conference. The proceeding will be published as a special volume in 'Discrete Mathematics'.

Lectures given:

Sergei Abramov: Solutions of linear differential equations in the class of sparse power series

Martin Aigner: Geometric representations of graphs and the four–color theorem

Eric Babson, Anders Björner, Svante Linusson, John Shareshian*, and Volkmar Welker: Complexes of not i-connected graphs

Frédérique Bassino: Distributions de longeurs des codes circulaires

Nantel Bergeron and Frank Sottile*: Identities of structure constants for Schubert polynomials and orders on S_n

Miklos Bona: P-recursiveness for pattern avoidance

Jonathan Borwein: Three adventures: Symbolically discovered identities for $\zeta(4n+3)$ and like matters

Richard Brak: Osculating lattice paths and alternating sign matrices

Will Brockman* and Mark Haiman: Nilpotent orbit varieties and the atomic decomposition of the q-Kostka polynomials

E. Rodney Canfield, Sylvie Corteel* and Carla D. Savage: Durfee polynomials

Christophe Carré and Sébastien Veigneau*: HUB, un concentrateur de ressources distribuées en combinatoire algébrique

Carol Chang: The $n!$ conjecture and an algebraic vector bundle on the Hilbert scheme of n points in the plane

Frédéric Chyzak: An extension of Zeilberger's fast algorithm to general holonomic functions

Mihai Ciucu: No feedback card guessing for dovetail shuffles

Robert Cori, B. Jacquard and Gilles Schaeffer*: Description trees for some families of planar maps

Vesselin Gasharov: Green and Gotzmann theorems for polynomial rings with restricted powers of the variables

Tom Halverson*, Robert Leduc and Arun Ram: Iwahori-Hecke algebras of type A, bitraces and symmetric functions

Philippe Jacquet* and Wojciech Szpankowski: Analytical depoissonization and its applications to combinatorics and analysis of algorithms

Anatol N. Kirillov and Toshiaki Maeno*: Quantum double Schubert polynomials, quantum Schubert polynomials and Vafa-Intriligator formula

Ulrich Kortenkamp and Jürgen Richter-Gebert*: Cinderella's Café — Interactive geometry on your computer

Daniel Krob* and Jean-Yves Thibon: A crystalizable version of $U_q(gl_N)$

Sévéverine Leidwanger: A relation between Schur P- and S-functions

Cristian Lenart: Symmetric functions, formal group laws, and Lazard's theorem

Nicolas Magot and Alexander Zvonkin*: Belyi functions for Archimedian solids

David K. Maslen: The computation of Fourier transforms on the symmetric group

Michel Mendes-France: The ultra divergent series $\sum_{n=0}^{\infty} \frac{1}{0^{2^n}}$
Stephen C. Milne: New infinite families of exact sums of squares formulas, Jacobi elliptic functions, and Ramanujan's tau function
Jean-Christophe Novelli: On the hypoplactic monoid
Andrei Okounkov: Binomial formula for Macdonald polynomials and applications
Yuval Roichman: Murnaghan-Nakayama and Littlewood-Richardson type rules for Kazhdan-Lusztig representations of Coxeter groups
Abdus Salam: Using the software EBENMASS for the symmetric groups and symmetric functions
Bruno Salvy: The combinatorics library of the project 'algorithms' at INRIA
Rodica Simion: Noncrossing partitions
Sheila Sundaram: Homotopy and homology of non-modular partitions and related posets
Brian Taylor: Straightening laws for row-convex tableaux

PROGRAMS IN 1997

Ergodic theory and dynamical systems

Organized by A. Katok, K. Schmidt, G. Margulis, January 1 – August 30.
10 Preprints contributed: [424], [425], [428], [433], [439], [484], [494], [497], [503], [519],
Money spent: AS 994.748.- (ESI), AS 549.928.– (foreign)

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

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

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

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

(1) Eskin, Kleinbock, Margulis, and Shah gave six lectures on flows on homogeneous spaces and number theory, in which they presented connections between arithmetical results connected with the Raghunathan conjecture and its solution, and striking new results on diophantine approximation and related questions.
(2) Katok and Schmidt gabe a series of four lectures on actions of higher-rank abelian groups and rigidity, in which they presented a variety of rigidity results (such as cohomological rigidity, isomorphism rigidity, perturbation rigidity and scarcity of invariant measures) for geometric and algebraic actions of $\mathbb{Z}^d$ and $\mathbb{R}^d$ with $d \geq 2$.
(3) Burger and Mozes gave three lectures on lattices in the automorphism group of a product of trees in which they presented new results and examples both in the theory of infinite groups and in multidimensional shifts of finite type.

(4) Besson and Courtois described their landmark results on the geometry of manifolds with geodesic flows of minimal entropy in three lectures.
(5) Feres gave three lectures on topological superrigidity which centered around his joint work with Labourie on cocycle superrigidity in the absence of invariant measures.

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

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

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

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

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

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

A. Katok, K. Schmidt

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

M.Ya.Antonovskii: 1965 School in Ergodic Theory at Humsan, Uzbekistan. Reflections and recollections of the organizer.
A.Katok: Ergodic theory from Humsan to Vienna.
H. Furstenberg: Stiffness of group actions
G. Knieper: Volume growth and the distribution of closed geodesics in manifolds of nonpositive curvature.
B.Leeb: Groups quasi-isometric to symmetric spaces.
B.Farb: Quasi–isometry and rigidity: latices and beyond.
E.Ghys (ENS-Lyon): Smooth linearizations of SL(n) actions around a fixed point
I.Benoist (Paris VII): Linear groups with positive eigenvalues

G.Tomanov (U.Lyon): On the quadratic and unitary inequalities in the S-adic case.
P.Foulon (Strasbourg): Dynamical rigidity in Finsler geometry.
V.Kaimanovich (Rennes): Singularity of the harmonic measure on symmetric spaces.
H. Abels (Bielefeld): A quantitative version of finite generatedness for lattices.
W.Ballmann (Bonn): Property T for groups acting on complexes.
U.Hamenstaedt (Bonn): Cocycles, cross-ratios and eigenfunctions in negative curvature.
F. Grunewald (Dusseldorf): On ternary quadratic forms.
P de la Harpe (Geneva): Growth on root lattices and Ehrhart polynomials.
I.Goldsheid (London): Zariski dense semi-groups of Lie groups: propertoes of eigenvalues and invariant sets.
A.Starkov (Istra): Closures of horospherical leaves on hyperbolic manifolds
G.Soifer (Bar-Ilan): Discontinuous groups of affine transformations with orthogonal linear part
S.Katok (Penn State): Automorphic forms of the complex hyperbolic space
S.Hurder (Illinois-Chicago): Boundary Chaos for open manifolds
S.Adams (Minnesota): Dynamics on Lorentz manifolds.
C-B.Yue (Penn State): On the representation variety of complex hyperbolic Kleinian groups.
Y. Gao (Yale): Superrigidity for isometric group actions on CAT(-1) spaces
A.Torok (Princeton): Regularity and rigidity of cocycles
V.Nitica (Indiana): Cocycles over Anosov actions.
N.Qian (Yale): Tangential flatness and local rigidity of higher rank lattice actions.
A.Wilkinson (Norstwestern): Prevalence of non-Lipschitz Anosov foliations and conjugacies.
E.Gutkin (USC): Polygonal billiards and cofinite lattices.

Program on Mathematical Relativity

Organized by B. Beig, ESI, 1.1.–30.6.1997.
6 Preprints contributed: [467], [460], [475], [507], [515], [524]
Money spent: AS 391.000.- (ESI), AS 4.000.– (foreign).

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

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

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

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

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

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

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

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

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

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

Organized by Lionel Mason,, Pawel Nurowski, Helmuth Urbantke. March, April and June, July 1997.

17 Preprints contributed: [432], [434], [451], [461], [464], [470], [471], [477], [486], [487], [493], [505], [516], [518], [520]; [521], [522].

Money spent: AS 518.500.-(ESI).

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

1) Particular attention was paid to analytic subtleties associated with the Robinson theorem. The theorem in its original version says, in particular, that if a space-time $\mathcal{M}$ admits a congruence of shear-free and null geodesics k then there exists a null Maxwell field associated with k in $\mathcal{M}$. Discussing this T. Bailey, D. Hill, L. Mason, P. Nurowski, I. Robinson, G. Sparling, J. Tafel, A. Trautman, H. Urbantke found examples of nonanalytic but smooth congruences of shear-free and null geodesics which do not admit any solution to the Maxwell equations for the associated null 2-form. This means that the Robinson theorem as quoted above needs some additional assumptions (e.g. analyticty or realizability) as conjectured by Tafel in 1985. Our examples are based on the relation between congruences of null geoedesics and 3-dimensional CR-manifolds associated with them. The main arguments in the construction of the examples are as follows.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Suggestions for future activity.

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

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

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Preprints contributed: 432, 434, 451, 461, 464, 470, 471, 477, 486, 487, 516, 518, 520, 521, 522.

Local Quantum Physics

Organized by D. Buchholz, H. Narnhofer, J. Yngvason, September 1 – December 31, 1998
11 Preprints contributed: [446], [448], [449], [469], [496], [498], [499], [501]; [525], [528], [529].
Money spent: AS 883.000.- (ESI), AS 435.000.– (foreign)
Part of the program was the

Workshop on local quantum physics. September 29 - October 4, 1997
Lectures given:
R. Haag (Neuhaus/Schliersee): Objects, events and localization in quantum theory
R. Stora (Annecy): Memories about renormalized perturbation theory
K. Fredenhagen (Hamburg): Local (perturbative) construction of interacting fields on curved spacetime
I. Ojima (Kyoto): Spontaneous collapse of supersymmetry
H. W. Wiesbrock (Berlin): On modular theory and its application to physics
J. Roberts (Rome): New directions in superselection theory
O. Steinmann (Bielefeld): Particles as localized objects in quantum field theory
S. Doplicher (Rome): On the C*-algebra of a Hilbert bimodule
M. Müger (Rome): Superselection structure of massive quantum field theories in 1+1 dimensions
K. H. Rehren (Hamburg): Statistics and modular theory of solitons
H. J. Borchers (Göttingen): On the embedding of von Neumann algebras
B. Schroer (Berlin): Modular localization, H-temperature and bootstrap formfactor program
D. Guido (Rome): Superselection structure of conformal nets and applications to quantum field theories in curved spacetimes.
S. Summers (Gainesville): Geometric modular action and spacetime symmetry groups
M. Wollenberg (Leipzig): An inverse problem in modular theory
E. Seiler (Munich): Continuum limits of spin models and local cohomology
F. Strocchi (Pisa): Fermion boundary conditions and vacuum parameters
N. Landsman (Cambridge): Theta-angles and anomalies in QFT
G. Morchio (Pisa): Generalized Weyl systems
U. Moschella (Como): De Sitter quantum field theory: Introduction and applications
F. Bros (Saclay): Quantum field theory in de Sitter universe.
B. S. Kay (York): Quantum fields in non globally hyperbolic spacetime
H. Grosse (Vienna): Simple field theoretical models on non-commutative manifolds
W. Junker (Potsdam): On a Euclidean approach to QFT on curved spacetimes
R. Verch (Göttingen): On wavefront sets and algebraic quantum field theory
R. Conti (Rome): On sectors with infinite statistics
C. D'Antoni (Rome): Extension of antiautomorphisms and the PCT symmetry
T. Matsui (Fukuoka): Classification of positive energy representations for massive lattice models
K. Baumann (Göttingen): On bounded Bose fields in 1+1 dimensions commuting for space- and time-like distances

More than 30 experts for the structural analysis in relativistic quantum field theory participated in this 3 month project at ESI and worked together on about 5 different but interrelated topics. The program was centered about an intense one-week workshop to which further researchers were invited. Beside it between 2 and 4 more informal talks were delivered each week by participants on an ad hoc basis. The topics covered in this project range from the structural analysis of nets of local algebras through problems in the theory of superselection sectors and thermal quantum field theory to quantum field theory on curved spacetime. In spite of this

diversity of problems there appears to be an almost universal mathematical tool for their treatment: modular theory. This intriguing fact was the leading theme in this project and its deeper understanding was one of the central goals. The results obtained provide further evidence to the effect that modular theory is a primary key to the understanding of local quantum physics. In the following an outline is given of the specific problems treated and results obtained by the participants of the project.

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

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

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

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

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

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

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

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

In a joint project D. Buchholz, S. Doplicher, G. Morchio, J.E. Roberts and F. Strocchi aimed at clarifying the localization properties of charged states in quantum electrodynamics. To this end an analysis of the classical Dirac-Maxwell theory, perturbative computations and a formal discussion in the indefinite metric formalism were carried out. The conclusion was that there is no obvious algebraic obstacle to localizing charged states on the algebra generated by the charge density and the magnetic field in a given Lorentz system. Since a mathematically satisfactory treatment of full quantum electrodynamics has not been accomplished yet, more

rigorous results seem presently out of reach. But the above findings support an old conjecture of J. Fröhlich according to which the electric charge has better localization properties than normally assumed. The present findings seem to be the key to a general structural analysis of the charged superselection sectors in abelian gauge theories.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The preceding outline of activities reveals the broad spectrum of problems treated and the many interrelations between the various subjects. The fact that more new intriguing questions were raised during this project than answered provides evidence of the stimulating and fruitful

atmosphere at ESI. It is to be expected that a substantial part of the ongoing projects mentioned above will be finished within a few months and will result in further ESI-publications.

The efficient handling of all practical matters by the staff of the Institute and the excellent working conditions (apart from some minor shortcomings of the electronic equipment) were essential for the success of this project. There was unanimous agreement that this intensive exchange between experts working in quite different areas will have substantial impact on the future development of local quantum physics.

Nonlinear theory of generalized functions

Organized by M. Oberguggenberger (Innsbruck), September – December 1997

5 Preprints contributed: [502], [508], [511], [512], [513].

Money spent: AS 518.500.- (ESI), AS 124.000.– (foreign)

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

There were 30 invited visitors, 4 guests from abroad visiting on their own, and 10 - 15 mathematicians and physicists from Vienna participating regularly in research and discussions.

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

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

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

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

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

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

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

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

Penney model and limiting behavior for positive measures as potential; generalized solutions to the linear Schrödinger equation with additive white noise.

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

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

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

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

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

As a result of interaction with the ESI-program "Local Quantum Physics"

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

Publications. Apart from the ESI-preprints listed separately, a proceedings volume "Nonlinear Theory of Generalized Functions" of the workshop will be published in the Pitman Research Notes in Mathematics Series. The proceedings volume will contain short review articles on the fields represented by the participants, in their interaction with the questions of nonlinearity and singularities as worked out during the program. It is intended as a survey of the state of the art in the field.

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

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

Collaborations initiated. Apart from various collaborations among participants already existing, a

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

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

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

February 5, 1998 Michael Oberguggenberger, Universität Innsbruck.

Programs of 1996

Condensed Matter Physics – Dynamics, Geometry, and Spectral Theory.

Topological, Conformal and Integrable Field Theory.

Representation Theory with Applications to Mathematical Physics.
preprints contributed: [488], [492]

Mathematical Problems of Quantum Gravity. Continuation of the 1996 program, organized by A. Ashtekhar and P. Aichelburg.

Money spent: AS 69.000.–(ESI).

19 Preprints contributed: [417], [418], [420], [422], [430], [441], [456], [457], [458], [459], [462], [463], [472], [473], [474], [476], [509], [510], [517].

Hyperbolic Systems with Singularities.
16 Preprints contributed: [416], [423], [427], [429], [436], [437], [438], [442], [444], [445], [455], [468], [483], [489], [491], [504].

Guests via Director's shares

Guests of Walter Thirring.

Money spent: AS 44.000.– (ESI), 3.000.– (foreign).

5 Preprints contributed: [431], [440], [443], [478], [490]

Guests of Klaus Schmidt. Everything is included in the program report on Ergodic Theory.

Guests of Peter Michor.

Money spent: AS 146.000.–(ESI), AS 352.000.–(foreign)

16 preprints contributed: [415], [419], [426], [435], [452], [453], [454], [465], [466], [479], [482], [485], [496], [506], [514]; [523].

Guests of Hoffman-Ostenhof.

Hoffmann-Ostenhof is also the local coordinator of the EU TMR-network 96-0001 'Partial Differential Equations and Applications in Quantum Mechanics' (November 1996–October 2000, ca. AS 2.5 Mio to be spent at ESI), together with TU Berlin, University of Wales, Université de Paris-Sud, University of Kopenhagen, Universität Regensburg.

Money spent: AS 103.000.–(ESI), AS 365.000.—(foreign, EU)

8 preprints contributed: [421], [447], [480], [481], [495], [500], [514]; [527]

Guests of H. Grosse.

Money spent: AS 23.000.–(ESI), AS 2.000.—(foreign)

1 preprint contributed: [526]

Guests of A. Cap.

Money spent: AS 7.000.–(ESI).

preprints contributed: [450]

List of Preprints

We try to keep track of the bibliographical data of the published versions of the preprints – this is incomplete and we are constantly updating it. Papers in mathematics have been bibliographically completed up to Nr. 240. Therefore we enclose the list of all preprints, not only those of 1997.

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Wichmann Eyvind H., University Berkeley, 09 16-10 18, BYN
Wiesbrock Hans-Werner, FU Berlin, 09 16-10 03, BYN
Wilkinson Amie, Northwestern University, 08.02.-15.02. SCH
Williams Susan, University of South Alabama, 07 16-08 13, SCH
Wollenberg Manfred, Universtät Leipzig, 09 30-10 10, BYN
Woodhouse Nicholas M.J., University of Oxford, 06 23-07 05, UNM
Yokura Shoji, University of Kagoshima, Japan, 07 17-09 05, MI
Yue Chengbo, Pennsylvania State University, 06.02.-11.02. SCH
Yuri Michiko, Sapporo University , 08 03-08 25, SCH
Zhang Tusheng, University of Henan, China, 12 02-12 07, OGK
Zhao Guosong, China, 01 01-09 30, MI
Zoller Peter, Universität Innsbruck, 01 08-01 11, GRO