European Science Foundation

Standing Committee for Physical and Engineering Sciences (PESC)

ESF PESC EXPLORATORY WORKSHOP

Dynamical Systems: from Algebraic to Topological Dynamics

SCIENTIFIC REPORT

Max Planck Institute for Mathematics
Bonn, Germany, 4-10 July 2004

Convened by:

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Executive Summary

The ESF Exploratory Workshop "Dynamical Systems: from Algebraic to Topological Dynamics" was held in Bonn (Germany) in period from 4 to 10 July 2004. The workshop took place at the Hörsaal of the Max-Planck-Institut für Mathematik, which over the years gained much experience in hosting international activities, conferences and workshops. We believe the facilities provided an excellent setting for stimulating scientific discussions. The accommodation of the participants was at the Hotel Ibis (Vorgebirgsstrasse 33, Bonn) and Hotel Acora (Westpreussenstrasse 20-30, Bonn). The ESF workshop had 33 invited lecturers. The speakers were from the following 11 countries: Austria (2), France (5), Germany (5), Israel (2), Italy, Poland (3), Spain, Sweden, Ukraine, United Kingdom (3), United States (9).[1]

The topics of the workshop covered dynamical systems in a broad sense, their interplay and applications to natural sciences. Its main subjects were: asymptotic geometric analysis and (topological) transformation groups; arithmetic dynamics; C*-endomorphisms; actions of Polish groups; low-dimensional dynamics: rotation theory, smooth interval dynamics, area preserving diffeomorphisms and time-one maps on surfaces, Sharkovsky-type theorems, C^1-expanding maps and g- functions; interval exchange transformations and translation flow; number theory and dynamical systems; leafwise cohomology of algebraic Anosov diffeomorphisms; symbolic dynamics; multifractal analysis and Diophantine approximations; dynamics and moduli spaces; invariant measures and Littlewood's conjecture; flows on manifolds; translation surfaces and Abelian differentials, symbolic representations of toral automorphisms, Mahler measure and equivalence relations; statistical properties of dynamical systems; transfer operators for geodesic flows and Hecke operators; anisotropic Sobolev spaces, transfer operators for Anosov diffeomorphisms; amoebas and algebraic dynamics; shift operators on buildings and noncommutative spaces; topological orbit equivalence; theory of entropy and chaos.

The theory of dynamical systems is currently one of the important areas of mathematics, born with H. Poincare's "Les methodes nouvelles de la mechanique celeste" at the end of XIX century. Since 2000 it is given a separate heading in the Mathematical Reviews. Owing to its universal character, the theory uses methods from various branches of mathematical science (algebra, analysis, geometry, topology, ...). It has arisen from an attempt at an adequate description of phenomena in the surrounding world. Therefore it traditionally plays the role of the theoretical basis for various models in physics, biology, economics, etc. Nevertheless, at present also conversely, problems posed in the theory of dynamical systems penetrate other mathematical theories, giving them a fresh impulse, serving as a tool for solving complex problems within these theories and also opening completely new problems. Besides the classical branches of the dynamical systems theory (ergodic theory, topological dynamics, low-dimensional, smooth and complex dynamics) there have appeared new ones - algebraic

[1] All participants from non-ESF countries were scientific visitors of the MPI for that time.

and arithmetic dynamics. The main goal of the workshop was to stimulate co-operation among various branches of dynamics.

As already mentioned the main feature of this workshop lies in its multidisciplinary nature. Many historical examples prove that the most outstanding results in the field were obtained with the help of intuition, and sometimes even methods, from a priori different or even unrelated subjects. It may occur inside mathematics or physics or between the two sciences. There is no doubt that this multidisciplinary point of view has to be developed, as it constitutes a major source of discoveries. However, the different subjects in the field have grown exponentially, and mastering more than one of them becomes more and more difficult.

The aim of the workshop was to gather leading experts in many of the core areas of the theory of dynamical systems and in closely related areas in order to present a broad panorama of the current state of the knowledge in this part of mathematics and accelerate the research by fitting together expertise of the participants. A potential important European added value of the workshop would be the formation of strong new networks/projects across Europe.

Scientific Content of the Event

The scientific programmme consisted of five day sessions. The opening welcome was given by Professor F. Hirzebruch, Professor D. Zagier and Professor Yu. Manin. The scientific part of the meeting was opened by Professor L. Alseda, who reported his joint work with S. Ruette on rotation sets for graph maps of degree 1. In the case they established that, if the graph has a single loop S then the set of rotation numbers of points in S has some properties similar to the rotation set of a circle map. In the following talk, Professor H. Bruin presented his joint work with Weixiao Shen and Sebastian van Strien. He gave a talk on unique physical measures for typical unimodal polynomials. In particular, it was shown that for a one-parameter family of unimodal polynomials f(a) with even critical order $\geq$ 2, for almost all parameters a, f(a) admits a unique physical measure, being the equidistribution on a nonrepelling periodic orbit, and acip, or a measure supported on a Cantor set $\omega(c)$ where $f \mid \omega(c)$ is uniquely ergodic. Next, Dr. B. Fayad was the first of 11 young scientists of the meeting. In his talk, he presented a construction method providing area preserving weakly mixing diffeomorphisms on a manifold M equal to the 2-torus, the 2-annulus, or the 2-disc. In particular, he proved that on the 2-disk or 2-annulus, some parameter α is Diophantine if and only if there is no ergodic diffeomorphism of M whose rotation number on the boundary equals α. Weakly mixing property for interval exchange transformations and translation flow was considered by Dr. A. Avila. In his joint work with Giovanni Forni they proved that a typical interval exchange transformation is either weakly mixing or it is an irrational rotation. The next speaker was Professor P. Le Calvez. He was talking about the time-one maps of identity isotopies on surfaces and in particular, gave a detail proof of some results about homeomorphisms of surfaces which are time one map of an isotopy starting from the identity. The working day was closed by Professor J. Schmeling, who discussed the field of random coverings, shrinking targets and hitting time statistics.

Professor J. Auslander, a pioneer of algebraic methods in topological dynamics, started the second day by showing the latest advances of understanding the recurrence for general group actions. Next, Professor Ch. Deninger was speaking about leafwise cohomology of algebraic Anosov diffeomorphisms. He presented a joint work with Anton Deitmar and, in particular, he showed that the maximal Hausdorff quotient of the leafwise cohomology of a nilmanifold with respect to the unstable foliation of an algebraic Anosov diffeomorphism is finite dimensional. Professor E. Akin gave a survey on his resent paper on Mycielski sets in dynamical systems with a special attention to their role in theory of chaos. After the break, Professor T. Ward spoke about analogues of the prime number theorem and Merten's theorem for dynamical systems with non-hyperbolic behaviour. In the next 3 lectures of the day, the main theme was (topological) entropy. Professor M. Boyle gave a nice survey on the entropy theory of symbolic

extensions. It was a joint work with the next speaker, Professor T. Downarowicz, who spoke on the entropy structure. One of the main results of these two lectures is the Sex Entropy Theorem: for a homeomorphism T of a compact metric space X, a bounded function on the space of T-invariant Borel probabilities is a symbolic extension entropy function if and only if it is affine and a superenvelope of the entropy structure. In 1974 Michael Shub asked the following question: When the topological entropy of a continuous mapping of a compact manifold into itself is estimated from below by the logarithm of the spectral radius of the linear mapping induced in the cohomologies with real coefficients? This estimate has been called Entropy Conjecture (EC). After a survey of results on this conjecture, Professor F. Przytycki presented a joint work with W. Marzantowicz, were they proved the EC for all continuous mappings of compact nilmanifolds.

The Wednesday morning session was started by Dr. Ya. Vorobets, who spoke on periodic geodesics on generic translation surfaces. He discussed the properties of periodic geodesics on translation surfaces that hold for almost all elements of the moduli space, these include quadratic asymptotics of various growth functions and uniform distribution of directions of periodic geodesics. Next, Professor D. Fisher gave a survey on several Zimmer's conjectures concerning actions of large groups on low dimensional manifolds and discussed how he can produce L^2 invariant metrics for some cases of conjecture in an effective manner starting from an arbitrary metric. Professor F. Durand gave a characterization of the eigenvalues with a continuous eigenfunction. After the break, Professor C. McMullen discussed orbit closures and invariant measures for the action of SL(2,R) on the space of holomorphic 1-forms of genus two. In particular, he presented several new results on the complex geodesics, Raghunathan's conjectures, invariant measures and pseudo-Anosov mappings. Professor M. Einsiedler reported on joint work with A. Katok and E. Lindenstrauss about invariant measures on SL(3,R)/SL(3,Z) and Littlewood's conjecture. He gave a proof that the set of exceptions to Littlewood's conjecture in the theory of multi-dimensional Diophantine approximations has Hausdorff dimension zero. Next, Dr. M. Mirzakhani explained results of her study the ergodic properties of the earthquake flow on the bundle of geodesic measured laminations by using a relationship between the earthquake flow and the Teichmuller horocycle flow. She used these results to find the growth of the number of simple closed geodesics on a hyperbolic surface. The working day was closed by open problems session where the participants presented several open problems in the theory of Dynamical Systems. Some of them will be published on the web page " Open Problems in Dynamical Systems & Ergodic Theory".

Professor E. Glasner gave the first lecture in the fourth working day of the meeting. He talked on spatial and non-spatial actions of Polish groups. Symbolic representations of toral automorphisms, Mahler measure and equivalence relations on sequence spaces were considered by Professor K. Schmidt on the next lecture. It is a classical problem to study statistical properties of hyperbolic dynamical systems (e.g., distribution of closed orbits, Birkhoff sums etc.). In his talk, Professor M. Pollicott proved various distribution results involving shrinking intervals. This was illustrated by a pair correlation result, in which he counted the asymptotic number of pairs of closed geodesics the difference of whose lengths lies in intervals, which

are allowed to shrink at a sub-exponential rate. After the break, Professor M. Lemanczyk presented in his talk several resent results on dynamical systems of probability origin and flows on surfaces. The Sierpinski gasket is one of the best known examples of a self-similar fractal set and can be obtained as the limit set of a semigroup action generated by finitely many affine contractions. Considering this space as a Martin boundary of Markov chains one obtains a familiy of Martin metrics, different from the Euclidean metric. Professor M. Denker discussed fractal-geometric aspects of these Martin metrics on the Sierpinski gasket. Next, Professor Ch. Hoffman considered multiple invariant measures for C^1-expanding maps and g-functions. He showed that if the g-function has a certain modulus of continuity, then there is a unique stationary measure which is consistent with the g-function. This measure also has "nice" ergodic theoretic properties. But if it does not, then it is possible that there are multiple invariant measures which are consistent with the g-function. These measures may have many ergodic theoretic properties. The last talk of the day was given by Professor D. Lind. He surveyed some recent results in algebraic dynamics, emphasizing the role that amoebas, both complex and p-adic, play.

The concluding session consisted of seven talks. Professor G. Keller reported in his talk on joint work with R. Fabri, R. Johnson and T. Jäger about Sharkovsky-type theorem for minimally forced interval maps (this talk was announced as a celebration of 40 years of Sharkovsky theorem and its new perspectives). Next, Professor C. Liverani presented a unified approach to study the statistical properties of dynamical systems alternative to the one based on Markov partition. Such an approach yields stronger results in many cases and it is hoped to have a larger realm of applicability. Professor D. Mayer gave a nice survey and presented new results on transfer operators for geodesic flows on modular surfaces and Hecke operators for period functions. After the break, Professor V. Baladi talked on anisotropic Sobolev spaces and transfer operators for Anosov diffeomorphisms. In particular, she considered the transfer operator associated to an Anosov diffeomorphism with $C^{1+\alpha}$ unstable foliation, and showed good bounds on its essential spectral radius when acting on suitable Sobolev spaces. Next, Professor B. Weiss reported in his talk on joint work with J. Smillie about minimal sets for the horocycle flow and characterization of lattice. They explicitly described the minimal sets for the (Teichmuller) horocycle flow on the moduli space of quadratic differentials on a compact orientable surface and on an its stratum. Professor A. Vdovina was speaking about shift operators on buildings and noncommutative spaces. In her joint work with M. Marcolli they studied dynamical systems associated with group actions on two-dimensional buildings and constructed an operator algebra coming from a two-dimensional subshift induced by the group action. The meeting was closed by Professor O. Sarig who presented his joint work with F. Leddrappier on invariant Radon measures for horocycle flows on regular covers. They classified (non-trivial) ergodic invariant Radon measures in case the surface is a regular cover of a compact hyperbolic surface.

Assessment of the Results, Contribution to the Future Direction of the Field, Outcome

The workshop was very fruitful. The presentations of the participants gave an impressive overview of the activities of the major groups in Europe (and US) working in the area of Dynamical Systems and this was an important contribution to assess future trends and possible new direction of the field.

As a rule, each talk was followed by several stimulating questions, remarks and discussions, all in an informal and constructive atmosphere. It was a pleasure to see also vigorous discussions of the pairs or larger groups of participants at the corridors of the institute even late at night.

It was confirmed by the thanks of many participants that the programme of the workshop was very interesting, stimulating and wide-ranging, the workshop had a well-deserved success.

The direct results of this meeting are

1. the formation of a new European network spanning 11 countries of research groups active in Dynamical Systems;
2. publication of the proceedings volume of the activity of the MPIM on Algebraic and Topological Dynamics and the ESF workshop. The proceedings volume is expected to appear in the AMS Contemporary Mathematical series.

Final Programme

Sunday 4 July 2004

Evening — *Arrival*

Monday 5 July 2004

09.30 - 10.00 — **Workshop opening**
Welcome by Professor Dr. **F. Hirzebruch** (Honorary Director of the MPI), Professor Dr. **D. Zagier** (Managing Director of the MPI) and **Convenors**

Tea break

10.30 - 11.30 — **Alseda, Lluis** (Universitat Autonoma Barcelona, Spain)
Rotation sets for graph maps of degree 1
(joint work with Sylvie Ruette)

11.40 - 12.40 — **Bruin, Henk** (University of Surrey, UK)
Unique physical measures for typical unimodal polynomials
(joint work with Weixiao Shen and Sebastian van Strien)

Lunch

14.30 - 15.30 — **Fayad, Bassam** (Universite Paris 13, France)
Ergodicity of disc diffeomorphisms and their rotation number on the boundary

Tea break

16.00 - 17.00 — **Avila, Artur** (College de France, France)
Weak mixing for interval exchange transformations and translation flow
(joint work with Giovanni Forni)

17.10 - 18.10 — **Le Calvez, Patrice** (Universite Paris 13, France)
Time-one maps of identity isotopies on surfaces

18.20 - 19.20 — **Schmeling, Joerg** (Lund University, Sweden & MPI, Germany)
Random coverings, shrinking targets and hitting time statistics

Tuesday 6 July 2004

09.00 - 10.00 — **Auslander, Joseph** (University of Maryland, US & MPI, Germany)
Recurrence in zero-dimensional spaces

Tea break

10.30 - 11.30 — **Deninger, Christopher** (Universität Münster & MPI, Germany)
Leafwise cohomology of algebraic Anosov diffeomorphisms

11.40 - 12.40 — **Akin, Ethan** (The City College, CUNY, US & MPI, Germany)
Mycielski sets in dynamical systems

Lunch

14.30 - 15.30 **Ward, Thomas** (University of East Anglia, UK & MPI, Germany)
Orbit counting without hyperbolicity

Tea break

16.00 - 17.00 **Boyle, Mike** (University of Maryland, US & MPI, Germany)
The entropy theory of symbolic extensions
(joint work with Tomasz Downarowicz)

17.10 - 18.10 **Downarowicz, Tomasz** (Wroclaw U. of Technology, Poland & MPI, Germany)
Entropy structure

18.20 - 19.20 **Przytycki, Feliks** (Institute of Mathematics, PAN, Poland)
Entropy conjecture on nilmanifolds
(joint work with W. Marzantowicz)

Wednesday 7 July 2004

09.00 - 10.00 **Vorobets, Yaroslav** (Pidstryhach Institut, NASU, Ukraine & MPIM, Germany)
Periodic geodesics on generic translation surfaces

Tea break

10.30 - 11.30 **Fisher, David** (Lehman College – CUNY, US & MPI, Germany)
Effective estimates on invariant metrics and Zimmer's conjecture

11.40 - 12.40 **Durand, Fabien** (Université de Picardie Jules Verne, France & MPI, Germany)
Eigenvalues of linearly recurrent dynamical systems

Lunch

14.30 - 15.30 **McMullen, Curtis** (Harvard University, US & MPI, Germany)
Dynamics of SL_2(R) over moduli space

Tea break

16.00 – 17.00 **Einsiedler, Manfred** (University of Washington, US & University of Vienna, Austria & MPI, Germany)
Invariant measures on SL(3,R)/SL(3,Z) and Littlewood's conjecture
(joint work with A.Katok and E. Lindenstrauss)

17.10 – 18.10 **Mirzakhani, Maryam** (Harvard University, US & MPI, Germany)
Ergodic theory of the earthquake flow

18.20 – **Open problems session**

Thursday 8 July 2004

09.00 - 10.00 **Glasner, Eli**(Tel Aviv University, Israel & MPI, Germany)
Spatial and non-spatial actions of Polish groups

Tea break

10.30 - 11.30 **Schmidt, Klaus** (ESI & University of Vienna, Austria & MPI, Germany)
Symbolic representations of toral automorphisms, Mahler measure and equivalence relations on sequence spaces

11.40 - 12.40	**Pollicot, Mark** (University of Manchester, UK) **Pair correlations for closed geodesics**
	Lunch
14.30 – 15.30	**Lemanczyk, Mariusz** (Nicholas Copernicus U., Poland & MPI, Germany) **Dynamical systems of probability origin and flows on surfaces**
	Tea break
16.00 – 17.00	**Denker, Manfred** (Georg-August-Universität, Goettingen, Germany) **Sierpinski walks**
17.10 – 18.10	**Hoffman, Christopher** (University of Washington, US & MPI, Germany) **Multiple invariant measures for C^1-expanding maps and g- functions**
18.20 – 19.20	**Lind, Douglas** (University of Washington, US & MPI, Germany) **Amoebas and algebraic dynamics**
20.00 –	**Workshop Dinner**

Friday 9 July 2004

09.00 - 10.00	**Keller, Gerhard** (Universität Erlangen, Germany & MPI, Germany) **Sharkovsky-type theorem for minimally forced interval maps** (joint work with R. Fabbri, R. Johnson and T. Jäger)
	Tea break
10.30 - 11.30	**Liverani, Carlangelo** (University of Rome Tor Vergata, Italy) **Banach spaces adapted to Anosov systems**
11.40 - 12.40	**Mayer, Dieter** (Institut für Theoretische Physik, Clausthal, Germany) **Transfer operators for geodesic flows on modular surfaces and Hecke operators for period functions**
	Lunch
14.30 – 15.30	**Baladi, Viviane** (Institut de Math. de Jussieu, France) **Anisotropic Sobolev spaces and transfer operators for Anosov diffeomorphisms**
	Tea break
16.00 – 17.00	**Weiss, Barak** (Ben Gurion University, Israel & MPI, Germany) **Minimal sets for the horocycle flow and characterization of lattice** (joint work with J. Smillie)
17.10 – 18.10	**Vdovina, Alina** (Universität Bonn, Germany) **Shift operators on buildings and noncommutative spaces** (joint work with Matilde Marcolli)
18.20 – 19.20	**Sarig, Omri** (Pennsylvania State University, US & MPI, Germany) **Invariant Radon measures for horocycle flows on regular covers** (joint work with F. Ledrappier)

Saturday 10 July 2004

Morning	*Departure*

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Statistical information on participants

The total number of participants was equal to 35. They were from the following 11 countries: Austria (2), France (5), Germany (5), Israel (2), Italy (1), Poland (3), Spain (1), Sweden (1), Ukraine(2), United Kingdom (4), US (9) (All participants from non-ESF countries were scientific visitors of the MPI for that time).

11 of lecturers were younger than 40 years of age.

70% of the participants of the workshop were from the ESF countries.