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MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 37/1986

Ergodentheorie und dynamische Systeme

17.8. bis 23.8.1986

Die Tagung fand unter der Leitung von Herrn Prof.Dr. M. Denker (Göttingen) und Herrn Prof.Dr. S.J. Patterson (Göttingen) statt. Im Mittelpunkt des Interesses standen Fragen der Ergodentheorie, verschiedener hyperbolischer geometrischer dynamischer Systeme und deren Zusammenhänge.
Ziel der Tagung war es, Kollegen verschiedener Arbeitsrichtungen zusammenzubringen und Diskussionen zwischen ihnen zu fördern. Tatsächlich war die Woche durch intensive Diskussionen und Gespräche gekennzeichnet, die zwischen verschiedenen Fachkreisen stattfanden. Während der Tagung wurden 24 sechzigminutige Vorträge gehalten. Es nahmen 35 Mathematiker aus 9 Nationen teil.

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Vortragsauszüge

J. AARONSON

Ways in which transformations preserving infinite measures are normalized inside each other

An infinite measure space has no canonical normalization and so arbitrary normalizations should be allowed for in the definition of "factor map" between m.p.ts of $\mathbb{R}$. For $T=(X_T, R_T, m_T, T)$ and $S=(X_S, R_S, m_S, S)$ m.p.ts of $\mathbb{R}$ and $c \in (0,\infty)$, a c-map of T onto S should be a map $\pi: X_T \to X_S \ni \pi^{-1}B_S \subseteq B_T$, $\pi T = S\pi$, $m_T \circ \pi^{-1} = c \cdot m_S$ (written $\pi: T \overset{c}{\to} S$). The collection $\Delta(T) = \{c \in (0,\infty): \exists$ c.e.m.p.t U and $\varphi: U \overset{1}{\to} T, \Phi: U \overset{c}{\to} T\}$, defined for a c.e.m.p.t T, reflects the ways T is normalized in its extensions. $\Delta(T)$ is an analytic subgroup of $(0,\infty)$. If S and T are similar (have a common extension) then $\Delta(S) = \Delta(T)$. For rationally ergodic m.p.ts $\Delta(T) = \{1\}$. $\Delta(T)$ can be : any countable subgroup of $(0,\infty)$, $(0,\infty)$ and also can have arbitrary Haussdorff dimension . This is because the group of invariant translations of an ergodic invariant measure on R appears as $\Delta(T)$.

W. BALLMANN

Surfaces without conjugate points

A Riemannian manifold M does not have conjugate points if, for any two points $p,q \in M$ and any curve connecting p and q, there is a unique geodesic connecting p and q which is homotopic to c. On such manifolds one can construct horospheres. By example it was shown that the horospheres do not necessarily depend continously on their center in the C^2-topology. The example was constructed by the speaker in joint work with M.Brin and K.Burns.

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R. BROOKS

Limit sets and circle packings

In this talk, we prove the following

Theorem: Let Γ be a geometrically finite Kleinian group without cusps. Then there exist arbitrarily small quasi-conformal deformations Γ_ε of Γ, such that Γ_ε is contained in a co-compact group.

The idea of the proof is to parameterize the deformation space of Γ according to how one may pack circles on the "ends" of $\mathbb{H}^3/\Gamma$. Given four circles forming a curvilinear rectangle, one may place either a "horizontal" or a "vertical" circle which touches three sides of the rectangle. Continuing this process indefinitely, one forms the continued fraction $n_1+1/(n_2+1/(n_3+\ldots$ corresponding to this rectangle. One proves, that this parameter varies continously as one varies the circles, and that deformation of Γ are parametrized by these continued fraction coordinates. To prove the theorem, one varies Γ by ε until these coordinates are all rational.

R. BURTON

The Central Limit Theorem for Dynamical Systems

(joint work with M.Denker) Let (X,T,μ) be an aperiodic dynamical system, that is a Lebegue measure space with probability measure μ and $T:X\to X$ is a measurable, measure-preserving transformation with $\mu\{x\in X \mid \exists n,\ T^n x=x\}=\emptyset$. It is shown that there always exist functions $f\in L^2(\mu)$ with $\int f d\mu=0$ satisfying the Central Limit Theorem, i.e. if $S_m f=f+Tf+\ldots+T^{m-1}f$ and $\sigma_m=\|S_m f\|_2$ then $\sigma_m\to\infty$ and $\mu\{x\in X \mid S_m f(x)/\sigma_m<t\}\to(\sqrt{2\pi})^{-1}\int_{-\infty}^{t}\exp(-u^2/2)du$ as $m\to\infty$.

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S.G. DANI

Dynamics on homogenous spaces

Let G be a connected Lie group and C be a closed subgroup of G, such that G/C admits a finite measure invariant under the G-action on the left. Let U be a horospherical subgroup of G (that is, there exist $g \in G$ such that $U=\{u \in G | g^j u g^{-j} \to e$ (the identity), as $j \to \infty\}$). We describe results on densitiy of orbits and the closures of non-dense orbits of the U-action on G/C. In particular, if G is the orbit of a suitable closed subgroup H of G and the orbit closure admits a finite H-invariant measure. On the other hand, for a general Lie-group G as above, and a horospherical subgroup U acting ergodically on G/C, an orbit is dense if and only if its image in the maximal semisimple factor is dense.

We give some applications of the result to diophantine approximation in matrix set up.

P. EBERLEIN

Symmetry Diffeomorphism Group of a Manifold of Nonpositive Curvature

Let $\tilde{M}$ denote a complete, simply connected manifold of sectional curvature $K \leq 0$. Each point of $\tilde{M}$ determines a geodesic symmetry that fixes p and reverses all geodesics through p. Let G* denote the group of homeomorphisms of $\tilde{M}(\infty)$, the points at infinity consisting of asymptote classes of geodesics. Theorem: Let $\tilde{M}$ be irreducible and suppose that G* has an orbit in $\tilde{M}(\infty)$ that is not dense in $\tilde{M}(\infty)$. Then $\tilde{M}$ is a symmetric space of noncompact type and rank ≥ 2. This result can be used to give a simplified proof of the Gromov Rigidity Theorem as well as characterizations of symmetric spaces of noncompact type and rank at least 2 in terms of properties of the Tits geometry in $\tilde{M}(\infty)$. The main idea of the proof is to show that $\overline{G^*(x)} \supseteq \{\gamma_w(\infty) : w \in \Phi(v)\}$, where v is an arbitrary unit vector of $\tilde{M}$, $x=\gamma_v(\infty)$ and Φ is the holonomy group at the footpoint of v. The result then follows from a theorem of Berger.

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U. FIEBIG

Gyration numbers of automorphisms

We give a partial answer to the problem of constructing an element in $\prod_{n=1}^{\infty} \mathbb{Z}/n\mathbb{Z}$ that is not in the image of the automorphismgroup of any subshift of finite type under the Boyle-Krieger gyration-homomorphism. We solve the related problem for the subgroup that is generated by involutions.
Furthermore we give a formula how to compute the gyration numbers for an involution of a mixing subshift of finite type with irreducible inverse of the zeta-function. This formula is determined by the coefficients of the characteristic polynomial of the subshift and one belonging to the subshift restricted to the fixpoint set of the involution.

M. GERBER

Geodesic Flows on S^2

We describe some Riemannian metrics on S^2 with ergodic geodesic flow. A C^1-example was constructed by R.Osserman. Also, V.Donnay gave a C^{∞}-example with almost everywhere non-zero Lyapunov exponants which he conjectured was ergodic (preprint, 1986).
We give an example similar to Donnay's, but avoiding the attachment of long flat cylinders in his construction. We prove that our example is ergodic. Moreover if we perturb our metric (in C^r-topology, with agreement up to some finite order on three closed geodesics) then the resulting flow is still ergodic. Our collection of perturbed metrics includes a real analytic one. This is a joint work with Keith Burns.

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S. GLASNER

Distal and Semisimple Affine Flows

Let T be a topological group and Q a convex compact set. An affine flow (T,Q) is minimally generated if (T,X) where $X=\overline{ext(Q)}$, is minimal. We prove that a minimally generated, metric, distal flow is equicontinous. A flow is called semisimple if it is the union of its minimal sets. Our main result is that for a metric semi-simple minimally generated affine flow (T,Q) the minimal subflow (T,X) is strongly proximally equivalent to an isometric extension of a strongly proximal flow. When T is amenable it follows that (T,X) is a strongly proximal extension of an equicontinous flow. We also show how the Poulsen simplex provides an example of an affine flow which is both minimal and strongly proximal.

A. KATOK

Invariant families of cones and ergodicity of symplectic maps and Hamiltonian systems

Let M be a compact contact manifold, $f_t:M\to M$, $t\in\mathbb{R}$ be a $C^{1+\varepsilon}$ $(\varepsilon>0)$ contact flow on M, e.g. the geodesic flow on the unit tangent bundle to a compact Riemannian manifold. Fix a Riemannian metric on M. Let us assume that for each $x\in M\setminus E_o$ (E_o a closed invariant set s.t. $M\setminus E_o$ is connected) the space $Ker_x\alpha$ (α the contact flow) allows a decomposition $Ker_x\alpha = D_x^+ + D_x^-$ such that D_x^+ and D_x^- depend on x continously (not necessarily uniformly continously), the cone $K^+=\{u+v; u\in D_x^+, v\in D_x^-, \|u\|\geq\|v\|\}$ is invariant ($df_t K_x^+ < K_{f_t x}^+$) and for every $x\in M\setminus E_o$ there exit t such that the cones $K_{x,t}^+ = df_t\, K_{f_{-t}x}$ and $K_{x,t}^- = df_{-t}\, (T_{f_t x}\setminus K_{f_t x}^+)$ are disjoint.
Theorem: The flow f_t is ergodic.
There is a similar result for symplectic maps. Among the applications are the construction of a C^∞-metric on any compact 3-manifold with ergodic geodesic flow and uniformly treatment of some previously known results.

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S. KATOK

Reduction theory for Fuchsian groups

Let Γ be a Fuchsian group, i.e. a discrete subgroup of the group of isometries of the hyperbolic plane H^2, with $_\Gamma\backslash H^2$ compact. Let γ_1, γ_2 be two hyperbolic elements. In order to decide whether they are conjugate in Γ or, in geometrically language, whether they define the same closed geodesic in $_\Gamma\backslash H^2$, we develope a so-called reduction theory. It serves the same purpose as Gauss reduction theory of indefinite binary quadratic forms for $SL(2,\mathbb{Z})$ based on continued fractions. An important ingredient in the argument is a construction of two expanding maps on the boundary $f_\pm: S^1 \to S^1$ associated to Γ. This construction is a generalization of that used by Bowen and Series.

M. KEANE

Uniqueness of infinite clusters in two-dimensional percolation

Consider a probalistic situation in which each of the sites of the two-dimensional square lattice (i.e. each point in $\mathbb{Z}^2$) is occupied or vacant, specified by a probability measure μ on $\{0,1\}^{\mathbb{Z}^2}$, 1 meaning "occupied". The occupied sites of any configuration fall apart into maximal connected subsets (z and z' are connected if $|z-z'|=1$) called occupied clusters. Denote by N the number of infinite occupied clusters . Suppose that μ is invariant and ergodic under horizontal and vertical translations separately, invariant under horizontal and vertical axis symmetries, and that $\mu(A\cap B) \geq \mu(A)\mu(B)$ for all A,B increasing (FKG or ferromagnetic condition). Then N is μ-a.e. constant, and we prove that either N=0 or N=1 with probability one, in joint work with A.Gandolfi (Delft) and L.Russo (Rome). The proof is by an application of a version of the multiple ergodic theorem combined with topological properties of paths in $\mathbb{Z}^2$.

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G. KELLER

Zeta-functions for piecewise monotonic transformations

The folloing result on piecewise monotonic interval maps T with a finite number of monotonic branches is reported: Suppose that each monotone branch of T extends analytically to a complex neighbourhood of its monotonicity interval. Let $\vartheta := \lim_{n\to\infty} (\inf_x |T^{n\prime}(x)|)^{-1/n} < 1$ (i.e. some T^n is piecewise expanding). Then there is a Markov-extension $(\hat{X},\hat{T})$ of $([0,1],T)$ and a Banach-space H of piecewise analytic functions defined on $\hat{X}$ such that the Perron-Frobenius operator $\hat{P}$ associated with $(\hat{X},\hat{T})$ acts quasicompactly on H with essential spectral radius ϑ. The zeta-function

$$\zeta(z) = \exp\Big(\sum_{n=1}^{\infty} z^n/n \sum_{x\in[0,1],\,T^n x = x} 1/|T^{n\prime}(x)|\Big)$$

extends analytically to $\{|z|<\vartheta^{-1}\}$, and if $|z|<\vartheta^{-1}$, then z is a zero of $1/\zeta$ with multiplicity m iff z^{-1} is an eigenvalue of $\hat{P}$ with multiplicity m. For the Perron-Frobenius operator P of $([0,1],T)$ we obtain as a corollary: If $|z|<\vartheta^{-1/2}$ and z^{-1} is an eigenvalue of P (acting on functions of bounded variation) of multiplicity m, then z is a zero of $1/\zeta$ of multiplicity m.

H. KRIETE

Simply connected immediate basins of attraction

Let R be a rational function of degree R > 1. Then $z_0=0$ is an attractive fixpoint of R with a simply connected immediate basin of attraction iff the following holds: There exists a holomorphic mapping $\Phi : D=\{z\in\mathbb{C} \,\big|\, |z|<1\} \to \bar{\mathbb{C}}$ with $\Phi(0)=0$ and a finite Blaschke-product B with $B(0)=0$ and $\Phi B = R\Phi$ on D. It turns out, that in this situation $\Phi(D)$ is the immediate basin of attraction of z_0 and simply connected. It is conjectured, that Φ is proper. This was shown in the following cases: 1.) $B(z)=\beta z^b$ with $|\beta|=1$, $b>1$

2.) $\deg(B) \leq \deg(R|\Phi(D))$

3.) $\deg(B)$ is a prime-number.

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F. LEDRAPPIER

Ergodic properties of the harmonic measure

Let $\tilde{M}$ be the universal cover of a compact manifold M with negative curvature, ν the harmonic class of measures on the absolute $\tilde{M}(\infty)$ and we identify in the natural way each unit-tangent sphere S_xM , $x \in M$ with $\tilde{M}(\infty)$. In this set-up we make the following remark: There exists a unique probability measure m on SM, invariant under the geodesic flow, where conditional measures on the fibration in spheres $\{S_xM, x \in M\}$ belong to the harmonic class. The measure m is a Gibbs state for some Hölder-function defined using the Green function on $\tilde{M}$.

N. MANDOUVALOS

The "Maass-Selberg" formalism for Kleinian groups

Let Γ be a Kleinian group acting on H^{n+1}. Then one of the fundamental problems is the spectral theory of the hyperbolic manifolds $\Gamma\backslash H^{n+1}$. There is a direct sum decomposition $L^2(\Gamma\backslash H^{n+1}) = L_0^2(\Gamma\backslash H^{n+1}) \oplus L_c^2(\Gamma\backslash H^{n+1})$, where L_0^2 is the space attached to the discrete part of the spectrum and L_c^2 is the space attached to the continous part of the spectrum and this is described by certain Eisenstein series. These Eisenstein series exist primarily in a certain region of the complex plane and the main problem is to continue them analytically in the whole complex plane and to find their functional equation. This problem is quite complicated and the main part of it consists of what we have called the "Maass-Selberg" formalism. This consists of the inner product formula and the "Maass-Selberg" relations. These relations allow one to modify the original Eisenstein series and produce L^2-versions of them in such an intrinsic way that one can evaluate their inner product in the space $L^2(\Gamma\backslash H^{n+1})$ in terms of objects which live on the boundary $\Gamma\backslash\Omega(\Gamma)$ of the manifold.

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M. MISIURWICZ

Peariodic orbits of maps of Y

The theorem ob Šarkovskič gives a full characterization of sets of natural numbers which can appear as the set of periods of all periodic points for continous maps of an interval into itself. We prove the analogous theorem (joint work with Ll.Alseda and J.Llibre) for the class of continous maps of $Y=\{z\in\mathbb{C}:z^3$ is real and $0\leq z^3\leq 1\}$ which keep 0 fixed (we denote this class $\mathcal{Y}$).

The main tool used in the proof is the notion of a primary orbit. A periodic orbit P of f from some class $\mathfrak{X}$ of maps is called primary if there exists $g\in\mathfrak{X}$ such that $g|_P = f|_P$ and g has no other periodic orbit of the same period as P. We prove that if a map $f\in\mathcal{Y}$ has a period orbit of period m then it also has a primary orbit of the same period. Then we find and classify all primary orbits of maps $f\in\mathcal{Y}$. This method may be used for further generalizations of the Šarkovskič theorem.

Z. NITECKI

Combinatorial Patterns for Maps of the Interval

Maps of the interval have a certain rigidity, indicated by the Šarkovskič theorem, which says that the existance of an orbit of period n for f forces orbits of period k which are determined by n independent of f. We investigate a similar relation for the combinatorial patterns represented by orbits. There are three areas in which we present results: 1:) Primary cycles: a cycle permutation of period $2^N q$ (q odd) which forces no other permutation of the same period is the top of a tower of N+1 extensions of specifiable type. 2:) Maximal cycles: a cycle permutation which is not forced by another of the same period is characterized by maximodality and a condition we call "semi-polarization". 3.) Intermediate forcing: If θ forces η, then assuming θ doesn't extend η and η is not a 2-extension, there is a rich structure of extensions of η forced by θ. Of the results above, 1.) were known previously; 2.) and 3.) represent very recent joint work of the speaker with M.Misiurewicz (some carried out at this conference).

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S.J. PATTERSON

A Lattice-point problem in hyperbolic space

Let Γ be a geometrically finite discrete group acting on (N+1)-dimensional hyperbolic space. Let $\delta(\Gamma)$ be the "exponent of convergence" of Γ. The leading term of the asymptotic development of the orbital counting function for Γ was determined if Γ is additionally convex-compact, extending earlier work of Lax-Phillips and others valid when $\delta(\Gamma)>N/2$. Essential to this determination is the use of Hopf's ergodic theorem to show that the analytic continuation of the resolvent kernel has no "resonances" on the line $Re(s)=\delta(\Gamma)$.

M. REES

Rational maps of degree two

I want to talk about an incomplete attempt to generalize the description - originally due to Douady and Hubbard - of the structure of the set of polynomials - especially of degree two - from the point of view of varying dynamics. The Julia set J(p) of a polynomial p (the set where the dynamics are non-trivial) is the boundary of the superattractive basin of ∞, and (J(p),p) is a quotient of $(\{z:|z|=1\}, z\mapsto z^2)$ if p has degree 2 and J(p) is locally connected, which is true, for instance, if p is in the Mandelbrot set and p is expanding on J(p), conjecturally a dense property. Variation of dynamics then translates into variation of identifications on $\{z:|z|=1\}$, and, for a polynomial of degree 2, it is known exactly which identifications occur if p is expanding on J(p). A rational map f of degree 2 can also be a quotient of $(\{z:|z|=1\}, z\mapsto z^2)$ on J(f), and, again, if f is expanding, there is a complete decomposition of the set of quotients occuring. But, in general, f is a quotient only on a Denjoy extension of $(\{z:|z|=1\}, z\mapsto z^2)$.

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M. SMORODINSKY

Normal subsequences for Markov Shifts and subshifts of maximal entropy

Champernowne (1933) gave a constructive example of a normal number to the base 10. Namely .0 1 2 3 4 5 6 7 8 9 0 1 0 2...09 11 12 ... We shall generalize Champernowne's construction to obtain explicit normal sequences for finite state Markov processes and for intrinsically ergodic subshifts (i.e. subshifts whose measure of maximal entropy is unique). As examples of the latter we have shifts of finite type and β-transformations [5]. For each n>0, $\Omega_n \subseteq S^n$, where S is the state space of the process, will be given. Then w_n will be formed by concatenating all elements of Ω_n (in any order), and the sequence is formed by concatenating the w_n's, $w_1\ w_2\ w_3$ ... In champernowne's construction $\Omega_n = S^n$. For Markov processes we will have to do little work to get the appropriate Ω_n, while for intrinsically ergodic subshifts the Ω_n will simply be all of the admissible n-blocks.

N.TH. VAROPOULOS

Recent results on Fuchsian groups

I examined the following two problems:
Problem 1: Let $\tilde{M}\underset{\pi}{\to}M$ be a Riemannian covering of M some compact Riemannian manifold. Find necessary and sufficient conditions for the existence of non trivial bounded harmonic functors on $\tilde{M}$.
Problem 2: Let Γ be a finitely generated Fuchsian group, let $\Gamma_1 \subset \Gamma$ be a subgroup, let $\delta(\Gamma)=\delta$ be the convergence exponent of Γ . Find conditions for the series $\sum_{\gamma\in\Gamma_1}(1-|\gamma|)^{\delta}$ to converge.
Problem 2 can be solved completely for $\Gamma_1 \triangleleft \Gamma$ and $1/2 \leq \delta \leq 1$.

D. WRIGHT

Circle packings arising in the boundary of Teichmüller space

This is a preliminary report on a still ongoing investigation into the space of Teichmüller space in an embedding due to B.Maskit.

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Here we limit ourselves to $T_{1,1}$, the space of once-punctured tori. For a given complex number μ, we consider the group G_μ generated by $S(z)=z+2$ and $T_\mu(z)=\mu+1/z$. Maskit realized $T_{1,1}$ as the set D of μ with $im(\mu)>0$ for which there are curves C_1, C_2 as shown :

$$T_\mu(C_2) = C_1$$
$$S(C_1) = C_1$$

It is known that D is a simply-connected domain containing $\{im(\mu)>2\}$. To any abstract generator X of the free group $\langle S;T_\mu\rangle$ there is one value of μ on ∂D such that Trace(X)=2. We present a combinatorial pattern in the limit sets (the "circle-packings" mentioned in the title) corresponding to these "cuspidal" groups. This leads to a combinatorial pattern in the choice of C_1, C_2. We hope this will show that ∂D is a simple continous curve.

A. ZDUNIK

Hausdorff and Gibbs measure on some invariant sets for holomorphic maps

Let Ω be a simply-connected domain in $\bar{\mathbb{C}}$ such that card$(\bar{\mathbb{C}}-\Omega)>2$. Let $R:D^2\to\Omega$ be a Riemannian mapping. R has nontangential limits a.e., thus the image $\omega=R_*\ell$ (ℓ is the Lebesgue measure) can be defined. The Hausdorff dimension of ω (being defined as infimum of Hausdorff dimensions of Y over all sets Y with $\omega(Y)=1$) is always equal to 1 if $\partial\Omega$ is a Jordan curve (Makarow,1985). Moreover, there exists a constant c such that ω is always absolutely continous with respect to the Hausdorff measure Λ_{ψ_c}, where $\psi_c(t) = t\cdot\exp\left(c\sqrt{\log(1/t)\log\log\log(1/t)}\right)$. Assume now, there is a holomorphic function $f:U\to C$, where $U\supset\partial\Omega$ and $\bigcap_{n=1}^{\infty} f^{-n}(\Omega\cap U)=\partial\Omega$. Then, it follows, that ω is "as singular as possible": there exists a $c_0>0$ such that for $c\le c_0$ ω is singular with respect to Λ_{ψ_c}, for $c>c_0$ it is absolutely continous with respect to Λ_{ψ_c}. Unless, $\partial\Omega$ must be an analytic curve. As an example, consider a family z^2+c. Then for any $c\neq 0,-2$ the measure ω on $\partial\Omega$ (where Ω is a basin of ∞) has this singularity property.

Berichterstatter: Hartje Kriete

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Tagungsteilnehmer

Prof. Dr. J. Aaronson

School of Mathematical Sciences
Tel-Aviv-University
Ramat Aviv

69978 Tel-Aviv
Israel

Prof. Dr. W. Ballmann

Mathematisches Institut der
Universität Bonn
Wegelerstr. 10

5300 Bonn 1

Prof. Dr. A. F. Beardon

Dept. of Pure Mathematics
University of Cambridge
16 Mill Lane

Cambridge CB2 1SB
Grossbritannien

Prof. Dr. R. Brooks

Department of Mathematics
University of Southern Calif.

Los Angeles, CA 90089-1113

USA

Prof. Dr. R. M. Burton

Department of Mathematics
Oregon State University

Corvallis, OR 97331

USA

Prof. Dr. S. G. Dani

School of Mathematics
Tata Institute of Fundamental
Research
Homi Bhabha Road

Bombay 400 005 / Indien

Prof. Dr. M. Denker

Institut für Math. Stochastik
Georg-August-Univ. Göttingen
Lotzestr. 13

3400 Göttingen

Prof. Dr. P. B. Eberlein

Department of Mathematics
University of North Carolina

Chapel Hill, N.C. 27514

USA

Ulf-Rainer Fiebig

Institut für Angew. Mathematik
Universität Heidelberg
Im Neuenheimer Feld 294

6900 Heidelberg

Prof. Dr. Marlies Gerber

Indiana University
Department of Mathematics
Swain Hall East

Bloomington, IN 47405
USA

Prof. Dr. S. Glasner

Department of Mathematics
Tel-Aviv-University
Ramat Aviv

Tel-Aviv, 69978
Israel

Boris Hasselblatt

Department of Mathematics
253-37
California Institute of Techn.

Pasadena, CA 91125
USA

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DFG Deutsche Forschungsgemeinschaft

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Dr. F. Hofbauer

Institut für Mathematik
Universität Wien
Strudlhofgasse 4

A-1090 Wien
Österreich

Hartje Kriete

Universität Bremen
Fachbereich Mathematik
Kufsteinerstraße

2800 Bremen 33

Prof. Dr. A. B. Katok

Department of Mathematics
253-37
California Institute of Techn.

Pasadena, CA 91125
USA

Prof. Dr. F. Ledrappier

Laboratoire de Probabilités
4 Place Jussieu
Tour 56

F-75230 Paris - Cedex 05
Frankreich

Prof. Dr. Svetlana Katok

Department of Mathematics
University of California

Los Angeles, CA 90024

USA

Prof. Dr. N. Mandouvalos

Department of Mathematics
University of London
King's College London

Strand, London WC2R 2LS
Grossbritannien

Prof. Dr. M. S. Keane

T. H. Delft
Onderafdeling der Wiskunde en
Informatica
Julianalaan 132

NL-2628 BL Delft

Prof. Dr. Lisa Martini

Sonderforschungsbereich 170
Universität Göttingen
Bunsenstraße 3-5

3400 Göttingen

Dr. G. Keller

Universität Heidelberg
Institut für Angew. Mathematik
Im Neuenheimer Feld 294

6900 Heidelberg

Prof. Dr. M. Misiurewicz

Institute of Mathematics
Warsaw University
PKiN IXp.

PL-00-901 Warschau
Polen

Prof. Dr. W. Krieger

Institut für Angew. Mathematik
Universität Heidelberg
Im Neuenheimer Feld 294

6900 Heidelberg

Prof. Dr. Z. H. Nitecki

Department of Mathematics
Tufts University

Medford, Mass. 02155

USA

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Prof. Dr. S. J. Patterson

Mathematisches Institut der
Universität Göttingen
Bunsenstr. 3-5

3400 G ö t t i n g e n

Prof. Dr. N. T. Varopoulos

Université Paris VI
Mathématiques
Tour 45-56, 5^{e}étage
4 place Jussieu

F-75230 P a r i s - Cedex 05

Prof. Dr. Chr. J. Preston

Fakultät für Mathematik
Universität Bielefeld
Universitätsstr. 1

4800 B i e l e f e l d 1

Dr. G. Weissenborn

Fachbereich Mathematik der
Technischen Universität Berlin
Straße des 17. Juni 135

1000 B e r l i n 12

Dr. Mary Rees

Dept. of Pure Mathematics
University of Liverpool
P.O.Box 147

L i v e r p o o l L69 3BX
Grossbritannien

Prof. Dr. D. J. Wright

Department of Mathematics
Oklahoma State University

S t i l l w a t e r , OK 74074
U S A

Prof. Dr. M. Smorodinsky

Department of Statistics
Tel-Aviv-University
Ramat Aviv

T e l- A v i v 69978
Israel

Dr. Lai-Sang Young

Fakultät für Mathematik
Universität Bielefeld
Postfach 8640

4800 B i e l e f e l d 1

Prof. Dr. R. J. Spatzier

Department of Mathematics
State University of New York

Stony Brook, New York 11794

U S A

Prof. Dr. Anna Zdunik

Institute of Mathematics
Warsaw University
PKiN IXp.

PL-00-901 W a r s c h a u
Polen

Prof. Dr. M. Urbański

ul. Szarych Szeregów 4A/15

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