DUBROVNIK VIII – Geometric Topology, Geometric Group Theory & Dynamical Systems

Inter – University Centre Dubrovnik, Croatia, June 22 – 26, 2015

Previous Dubrovnik conferences in this series:

Shape Theory and Pro-Homotopy, 1976
(organized by S. Mardešić)

Shape Theory and Geometric Topology, 1981
(organized by S. Mardešić & J. Segal)

Geometric Topology and Shape Theory, 1986
(organized by S. Mardešić & J. Segal)

Geometric Topology, 1998
(organized by I. Ivanšić, J. K. Keesling & R. B. Sher)

Geometric Topology II, 2002
(organized by A. N. Dranishnikov, I. Ivanšić, J. K. Keesling & Š. Ungar)

Dubrovnik VI – Geometric Topology, 2007
(organized by A. N. Dranishnikov, I. Ivanšić, J. K. Keesling & Š. Ungar)

Dubrovnik VII – Geometric Topology, 2011
(organized by M. Bestvina, A. N. Dranishnikov, J. K. Keesling, V. Matijević & Š. Ungar)

Organizers:

Mladen Bestvina, University of Utah
Alexander Dranishnikov, University of Florida
Jerzy Dydak, University of Tennessee
Vlasta Matijević, University of Split
José Sanjurjo, Universidad Complutense de Madrid
Sonja Štimac, University of Zagreb

http://web.math.pmf.unizg.hr/~sonja/Dubrovnik.html

Contents

Tentative Schedule (subject to change)

	Sunday, June 21, 2015				
6:00 - 8:00 PM	**Registration - Hotel Lero**				
8:00 - 10:00 PM	Welcome Party - Hotel Lero, at pool				

	Monday, June 22, 2015				
8:00 - 9:00	**Registration - IUC**				
9:00 - 9:10	Welcome (LLR)				
9:10 - 10:00	Agol (LLR)				
	Coffee Break				
	GGT (LR 2/2)	**GT (LR 5/2)**	**DS (LR 5/1)**	**CT (LR 4/2)**	
10:30 - 11:10	Brock	Ferry	Izydorek		10:30 - 10:45
					10:55 - 11:10
11:20 - 12:00	Bromberg	Okun	Janczewska		11:20 - 11:35
					11:45 - 12:00
12:00 - 1:00 PM	**Registration - IUC**				
	Lunch Break				
3:40 - 4:20	Canary	Eda	Sanjurjo	Barge	3:40 - 3:55
				Bertolini	4:05 - 4:20
4:30 - 5:10	Bridgeman	Koyama	Sánchez-Gabites	Miller	4:30 - 4:45
				De Capua	4:55 - 5:10
5:20 - 6:00	Kim	Willett	del Portal	Disarlo	5:20 - 5:35
				Erceg	5:45 - 6:00

	Tuesday, June 23, 2015				
9:00 - 9:50	Gabai (LLR)				
	Coffee Break				
	GGT (LR 2/2)	**GT (LR 5/2)**	**DS (LR 5/1)**	**CT (LR 4/2)**	
10:30 - 11:10	Vogtmann	Belegradek	Misiurewicz	Ageev	10:30 - 10:45
				Banakh	10:55 - 11:10
11:20 - 12:00	Algom-Kfir	Virk	Stimac	Dydak	11:20 - 11:35
				Zastrow	11:45 - 12:00
	Lunch Break				
3:40 - 4:20					
4:30 - 5:10	Charney	Babenko	Ishii	Bilan	4:30 - 4:45
				Uglešić	4:55 - 5:10
5:20 - 6:00	Feighn	Matic	Hazard	Hojka	5:20 - 5:35
				Johnson	5:45 - 6:00

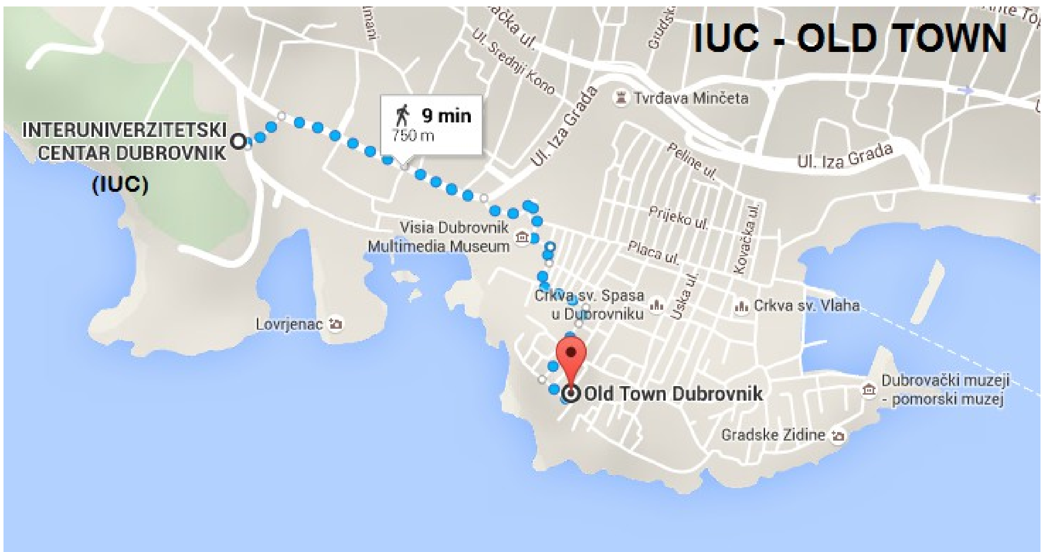
Wednesday, June 24, 2015 - Excursion
Departure from Hotel Lero at 9:00 AM

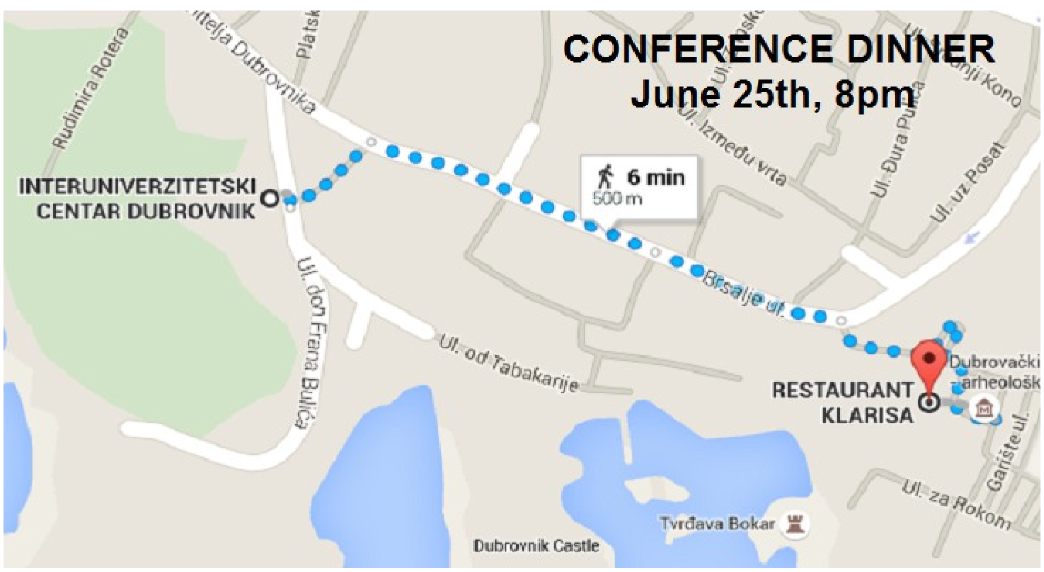
	Thursday, June 25, 2015				
9:00 - 9:50	Boyland (LLR)				
	Coffee Break				
	GGT (LR 2/2)	**GT (LR 5/2)**	**DS (LR 5/1)**	**CT (LR 4/2)**	
10:30 - 11:10	Guirardel	Levin	Tal	Misajleski	10:30 - 10:45
				Mine	10:55 - 11:10
11:20 - 12:00	Fujiwara	Gaifullin	de Carvalho	Megaritis	11:20 - 11:35
				Georgiou	11:45 - 12:00
	Lunch Break				
3:40 - 4:20	Aramayona	Lafont	Barge	Cencelj	3:40 - 3:55
				Gupta	4:05 - 4:20
4:30 - 5:10	Tao	Nowak	Kennedy	Clais	4:30 - 4:45
				Fink	4:55 - 5:10
5:20 - 6:00	Rafi	Melikhov	Kuperberg	Pfaff	5:20 - 5:35
				Pfaff	5:45 - 6:00
8:00	CONFERENCE DINNER IN THE RESTAURANT “KLARISA”				

	Friday, June 26, 2015				
9:00 - 9:50	Schwartz (LLR)				
	Coffee Break				
	GGT (LR 2/2)	**GGT (LR 5/2)**	**DS (LR 5/1)**	**CT (LR 4/2)**	
10:30 - 11:10	Przytycki	Groves	Oprocha	Zava	10:30 - 10:45
				Kawamura	10:55 - 11:10
11:20 - 12:00	Hilion	Cashen	Kwietniak	Yamauchi	11:20 - 11:35
					11:45 - 12:00
	Lunch Break				
3:40 - 4:20	Deverman (workshop, LLR)				
4:30 - 5:10	Sisto	Niblo	Boronski		4:30 - 4:45
					4:55 - 5:10
5:20 - 6:00	Horbez	Osin	Pilyugin		5:20 - 5:35
					5:45 - 6:00

GGT = Geometric Group Theory
GT = Geometric Topology
DS = Dynamical Systems
CT = Contributed Talks
LR = Lecture Room
LLR = Large Lecture Room, Ground Floor
IUC = Inter-University Centre, Address: don Frana Bulića 4, 20000 Dubrovnik, Croatia
Hotel Lero, Address: Iva Vojnovića 14, 20000 Dubrovnik, Croatia

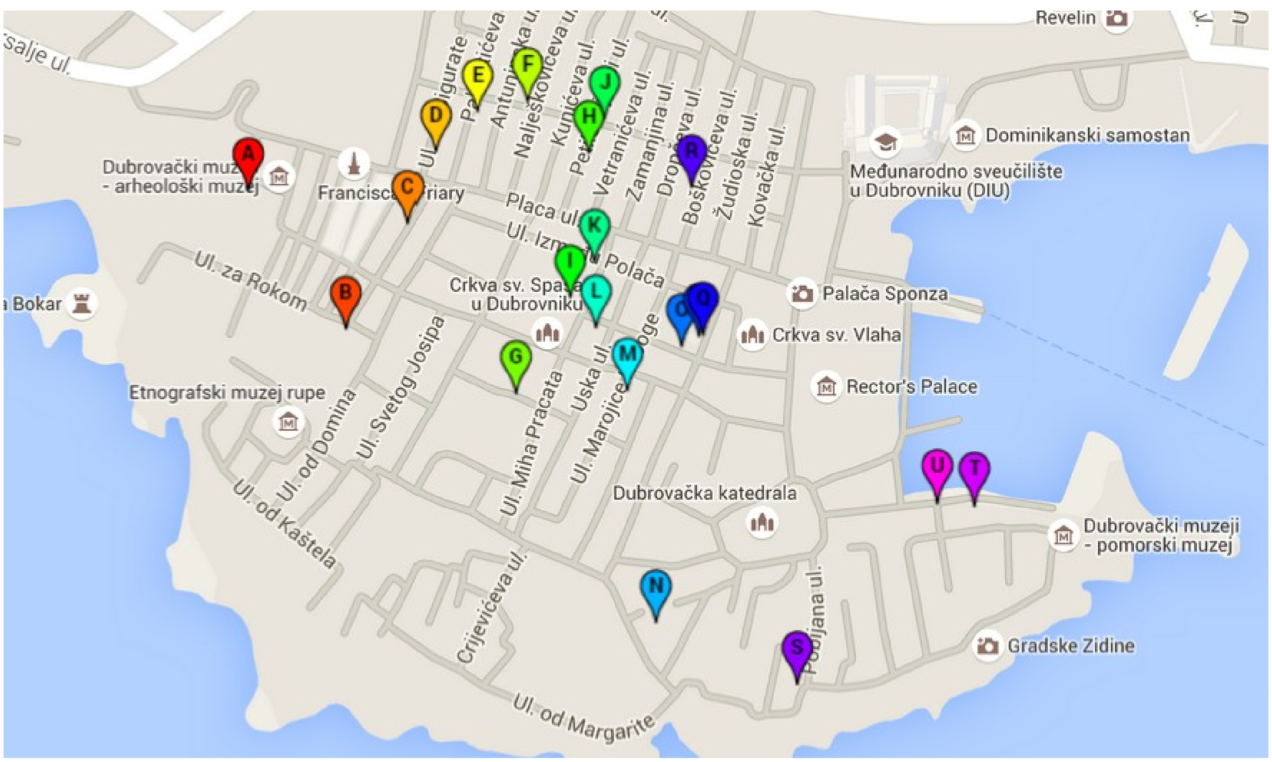

IUC - HOTEL LERO
Hotel Lero
Apartment Ana
Youth Hostel Dubrovnik
Dubrovnik - Babin Kuk DD
Ul. Iva Vojnovića
Ul. od Montovjerne
Ul. Gabra Rajčevića
Ul. Pera Čingrije
Splitski put
Ul. Vladimira Nazora
Hotel Bellevue Dubrovnik
Hotel Rixos Libertas Dubrovnik
Liechtensteinov put
Ul. Gorica Svetog Vlaha
Korčulanska ul.
23 min
1.8 km
20 min
1.6 km
17 min
1.4 km
Ul. branitelja Dubrovnika
Ul. Pera Bakića
Gornji Kono
Jadranska cesta
INTERUNIVERZITETSKI CENTAR DUBROVNIK
(IUC)
Google


IUC - OLD TOWN
INTERUNIVERZITETSKI CENTAR DUBROVNIK
(IUC)
9 min
750 m
Ul. Srednji Kono
Ul. Iza Grada
Tvrđava Minčeta
Ul. Iza Grada
Peline ul.
Prijeko ul.
Placa ul.
Kovačka ul.
Uska ul.
Visia Dubrovnik Multimedia Museum
Lovrjenac
Crkva sv. Spasa u Dubrovniku
Crkva sv. Vlaha
Old Town Dubrovnik
Dubrovački muzeji - pomorski muzej
Gradske Zidine


CONFERENCE DINNER
June 25th, 8pm
Rudimira Rotera
INTERUNIVERZITETSKI CENTAR DUBROVNIK
6 min
500 m
Ul. Između vrta
Ul. Đura Pulića
Ul. uz Posat
Branitelja Dubrovnika
Bršalje ul.
Ul. don Frana Bulića
Ul. od Tabakarije
RESTAURANT KLARISA
Dubrovački arheološki
Garište ul.
Ul. za Rokom
Tvrđava Bokar
Dubrovnik Castle

Places to eat (According to Tripadvisor with filters Lunch, Mid-range prices)

A) **Onofrio**, Poljana Paska Milicevica 3, Korean food
B) **Mea Culpa**, Za Rokom 3, Italian
C) **Presa**, Dordiceva 2, Fast food, sandwiches
D) **Portun**, Od Sigurate 2, Mediterranean, Croatian
E) **Nishta**, Prijeko bb, Vegetarian, Vegan
F) **Stara Loza**, Prijeko 24, French, Mediterranean, Contemporary
G) **Taj Mahal**, Nikole Gucetica 2, Indian, Pizza, European, Yugoslavian
H) **Gil's Little Bistro**, Petilovrijenci 4, French
I) **Konoba Dalmatino**, Miha Pracata 6, Seafood, Croatian
J) **Moskar Konoba**, Prijeko 16, Seafood, Mediterranean, Vegetarian, Croatian
K) **Pizzeria Petica 5**, Izmedu Polaca 7, Italian
L) **Segreto Pasta&Grill**, Cvijete Zuzoric 5, Italian
M) **Restaurant Dubrovnik**, Marojice Kaboge 5, Mediterranean, Croatian
N) **Konoba Jezuite**, Poljana Rudera Boskovica 5, Mediterranean, Croatian
O) **Bistro Teatar**, Ulica Cvijete Zuzoric 2, Mediterranean, Croatian
P) **Marco Polo Restaurant**, Lucarica 6
Q) **Oliva Pizzeria**, Lucarica 5, Italian
R) **Barba**, Boskoviceva 5, Fish & Chips, Seafood, Sandwiches, Mediterranean
S) **Azur Dubrovnik**, Pobijana 10, Asian, Mediterranean, Fusion, Asian fusion
T) **Pizzeria&Spaghetteria Storia**, Kneza Damjana Jude 6, Italian
U) **Konoba Ribar**, Damjana Jude bb, Italian, Seafood, Mediterranean, Croatian



Abstracts

Plenary Speakers

Veering triangulations and pseudo-Anosov flows

Ian Agol
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Coauthors: Franois Gueritaud

Attached to a pseudo-Anosov map of a surface, we associated a canonical ideal triangulation of the mapping torus punctured along the singular fibers called a veering triangulation. We'll survey some of the properties and open questions about these triangulations. Then we'll discuss an extension of the construction to pseudo-Anosov flows with certain properties. This is joint work with Franois Gueritaud.

Dynamics lifted to Abelian covers

Phil Boyland
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Lifting to a covering space helps unravel dynamics and the universal free Abelian cover is particularly useful for computing asymptotic averages. The lifted dynamics fall roughly into three cases depending on the growth of the action of a homeomorphism on first homology: exponential, polynomial and none. The results and objects of study vary in the three cases. Semiconjugacies, invariant decompositions and eigen-cocyles in the first, transitivity in the cover in the second, and rotation sets in the third. The strongest results are known for surface dynamics and in particular, for pseudoAnosov maps. We give a general introduction followed by sample results in each of the cases.

On the classification of Heegaard splittings

David Gabai
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Coauthors: Toby Colding (MIT) Dan Ketover (Princeton)

We discuss how geometric methods can be used to obtain an algorithm to enumerate without duplication the irreducible Heegaard splittings of closed non Haken hyperbolic 3-manifolds.

The Plaid Model and Outer Billiards

Richard Schwartz
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I will explain a combinatorial model which produces embedded polygons with integer-coordinate vertices. The model depends on a rational number parameter. It has a surprisingly rich combinatorial structure, exhibiting renormalization phenomena and a hierarchical structure. It is related both to outer billiards on kites and to Pat Hooper's Truchet tile system. I'll illustrate my talk with many computer pictures and demos.

Geometric Topology

Finite rigidity of curve complexes
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Coauthors: Christopher J. Leininger

A celebrated theorem of Ivanov, extended by Korkmaz and Luo, states that the curve complex C(S) of a surface is "simplicially rigid": every automorphism of C(S) is, except in a few well-understood cases, induced by an element of the mapping class group Mod(S). In this talk we will give a construction, for every surface S, of a finite subcomplex X(S) of C(S) that is also "rigid", in the sense that every injection of X(S) into C(S) is the restriction of an element of Mod(S). These finite rigid sets enjoy some curious properties; for instance, In the case of S a sphere with punctures, X(S) happens to coincide with the generator for the homology of C(S) identified by Birman-Broaddus-Menasco. We will then explain how to express C(S) as an increasing union of finite rigid sets, thus offering a new proof of the theorem of Ivanov-Korkmaz-Luo. Time permitting, we will describe an alternate proof of this latter result, due to Jesus Hernandez, which has interesting consequences to the rigidity of self-maps of C(S).

Spaces of nonnegatively curved metrics on surfaces
Igor Belegradek
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Coauthors: Jing Hu

I will survey recent progress on the spaces of nonnegatively curved metrics on the 2-sphere and the plane. The methods is a mix of infinite-dimensional topology and complex analysis.

Bounds on Renormalized Volume for Convex Co-compact hyperbolic 3-manifolds.
Martin Bridgeman
Boston College
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Coauthors: R. Canary

In this paper, we consider convex cocompact hyperbolic 3-manifolds and compare the convex core volume $V_C(M)$ to their renormalized volume $V_R(M)$. We show that they differ by a constant which depends only on the injectivity radius of the Poincare metric on the domain of discontinuity generalizing a recent result of Schlenker in the quasifuchsian case. We further show that the difference necessarily tends to infinity as the injectivity radius tends to zero and obtain an optimal description of the rate of divergence as the injectivity radius tends to zero.

Existence and uniqueness of group structures on covering spaces over groups

Katsuya Eda
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Coauthors: Vlasta Matijević

Let $f : X \to Y$ be a covering map from a connected space X onto a topological group Y and let $x_0 \in X$ be a point such that $f(x_0)$ is the identity of Y. We examine if there exists a group operation on X which makes X a topological group with the identity x_0 and f a homomorphism of groups. We prove that the answer is positive in two particular cases: if f is an overlay map over a locally compact group Y or if Y is locally compactly connected. In this way we generalize previously obtained results for overlay maps over compact groups and covering maps over locally path-connected groups. Furthermore, we prove that in both cases the group structure on X is unique.

[1] J. Dydak, *Overlays and group actions,* preprint.

[2] K. Eda, V. Matijević, *Finite-sheeted covering maps over 2-dimensional connected, compact Abelian groups*, Topology Appl. **153** (2006), 1033-1045.

[3] K. Eda, V. Matijević, *Covering maps over solenoids which are not covering homomorphisms*, Fundamenta Math.**221** (2013), 69-82..

[4] R. H. Fox, *Shape theory and covering spaces*, Lecture Notes in Math., Vol. 375, Springer, Berlin, 1974, pp 77-90.

[5] S. A. Grigorov, R. N. Gumerov, *On the structure of finite coverings of compact connected groups,* Topology Appl. **153** (2006), 3598-3614.

[6] S. Mardešić, V. Matijević, *Classifying overlay structures of topological spaces*,

[7] V. Matijević, *Classifying finite-sheeted covering mappings of paracompact spaces*, Revista Mat.Complut. **16** (2003), 311-327.

An Infiite-Dimensional Phenomenon in Finite-Dimensional Topology

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Coauthors: Alexander N. Dranishnikov, Shmuel Weinberger

The Gromov-Hausdorff metric is a metric on the isomorphism classes of compact metric spaces. The Gromov-Hausdorff distance from a metric space X to the 1 point metric space p is $(X)/2$, so being Gromov-Hausdorff close imposes little connection between the topologies of compact metric spaces.

However, if one assumes a uniform local contractibility condition, then much more structure is preserved. Let $\rho : [0, R) \to [0, \infty)$ be a function with $\rho(0) = 0$ and $\rho(t) \geq t$, such that ρ is continuous at 0. Following Borsuk and Gromov, we say that X is $LGC(\rho)$ if every ball of radius $r < R$ in X is nullhomotopic in the concentric ball of radius $\rho(r)$. Sufficiently Gromov-Hausdorff close n-dimensional $LGC(\rho)$ spaces are homotopy equivalent – and there are explicit estimates on the required degree of closeness in terms of n and ρ.

An old result of Ferry (for $n > 4$, the 3 and 4 follow from Freedman-Quinn and Perelman) shows that Gromov-Hausdorff close manifolds are often homeomorphic.

Theorem. For every n, and contractibility function ρ, precompact collections of closed $LGC(\rho)$ Riemannian manifolds in Gromov-Hausdorff space contain only finitely many homeomorphism types.

However, it can happen that for suitable precompact collections of closed Riemannian manifolds with contractibility function ρ, for every epsilon, there are epsilon-balls (not centered at manifolds!) containing more than one homeomorphism type.

Definition. We will say that closed manifolds M and N are deformation equivalentif there are paths M_t and N_t, $0 \leq t < 1$ in a pre compact subset of Gromov-Hausdorff space consisting of manifolds with contractibility function rho such that the Gromov-Hausdorff distance between M_t and N_t goes to zero as t approaches 1. It turns out that this relation is an equivalence relation. A manifold that possesses no nontrivial deformation is immutable.

Theorem 1. If M^m, $m \geq 7$, is a closed simply connected manifold such that $pi_2(M)$ vanishes, then there are manifolds which are deformation equivalent to M in a precompact collection of $LGC(\rho)$-manifolds for some rho if and only if $KO_m(M)$ has odd torsion.

For the general non-simply connected situation, there are additional secondary invariants that arise in the problem. These invariants are related to eta invariants, except that the familiar Atiyah-Patodi-Singer invariants usually give rise to torsion free invariants, and the generalization of them we need must contain torsion information.

We shall give a complete analysis of the deformation problem for dimensions ≥ 7. Here are some consequences and examples:

Theorem 2. For any M, the set of homotopy structures $f : M' \to M$ that are obtainable by deformations in some precompact subset of $LGC(\rho)$ manifolds in Gromov-Hausdorff space defines a subset $S^{CE}(M)$ that is an odd torsion subgroup of the structure group $S(M)$.

Theorem 3. If M has word hyperbolic fundamental group, or has fundamental group that is a lattice is a semisimple Lie group, $S^{CE}(M)$ is finite.

Theorem 4. There is a compact M such that $S^{CE}(M)$ is infinite.

The Borel conjecture is currently unresolved in its full generality, so the following corollary to our analysis is especially gratifying.

Theorem 5. If M is aspherical then $S^{CE}(M) = 0$.

Characterization of n-dimensional compacta in the product of n curves

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Coauthors: Jozef Krasinkiewicz a and Stanislaw Spiez (the Institute of Mathematics, Polish Academy of Sciences)

One of important embedding theorems in dimension theory was given by J. Nagata (1958): *Everyn-dimensional space, $n \geq 2$, can be embedded in the topological product $X_1 \times \cdots X_{n+1}$ of 1-dimensional spaces.* On the contrary Borsuk(1975) showed the following interesting result. *The 2-sphere $\mathbb{S}^2$ is not embeddable in any product of two curves. Analogous result holds for all spheres $\mathbb{S}^n$, $n \geq 3$.*

Motivated by these results, we investigated geometric, algebraic and combinatorial characterizations of n-dimensional compacta in the product of n 1-dimensional compacta. For example, we introduced a kind of generalized manifolds, called *quasi n-manifolds*, and showed that *if a locally connected quasi n-manifold X is in a product of n curves, then* rank $H^1(X) \geq n$. From a view point of algebraic way is the following: *if a compactum X is in a product of n curves and $H^n(X; G) \neq 0$ for some abelian group G, then $H^1(X; G) \neq 0$.* Those lead the above Borsuk's theorem.

We are showing results, topics and posing questions related to these embedding theorems.

Hyperbolic groups with boundary an n-dimensional Sierpinski space

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Coauthors: Bena Tshishiku

For $n > 6$, consider a torsion-free hyperbolic group G whose boundary at infinity is an $(n-2)$-dimensional Sierpinski space. I will explain why G must be the fundamental group of an aspherical n-manifold with non-empty boundary. Concerning the converse, for each $n > 3$, there are aspherical n-manifolds with boundary, with hyperbolic fundamental group G, whose boundary at infinity is *not* homeomorphic to Sierpinski $(n-2)$-space.

Unstable Intersection Conjecture

Michael Levin
Ben-Gurion University of the Negev
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Compact metric spaces X and Y are said to unstably intersect in R^n if any maps from X and Y to R^n can arbitrarily closely be approximated by maps with disjoint images. The Unstable Intersection Conjecture asserts that X and Y unstably intersect in R^n if and only if dim X $\times$ Y ¡n. We present recent results leaving this conjecture open only in the case dim X =dim Y =3, dim X $\times$ Y=4 and n=5.

Algebraic topology of non-compact non-ANRs with applications in geometric topology

Sergey Melikhov
Steklov Math Institute (Moscow)
`melikhov@mi.ras.ru`

Homology and cohomology theories are well-understood for (separable) polyhedra and for (metrizable) compacta — in other words, for countable unions *or* sequential inverse limits of compact polyhedra. Here "well-understood" means, in particular, axiomatic description — which is by the usual axioms of Eilenberg and Steenrod with Wallace's strong excision and the two infinite additivity axioms of Milnor (see [P] for the case of ordinary theories). Let us note that this description incidentally excludes pathological theories (such as singular) and refines homotopy invariance to (strong) shape invariance.

In contrast, homology and cohomology of non-compact non-ANRs are far from being well-understood, because direct and inverse limits of abelian groups do not commute in general. Here are three old examples.

1) The two computations of complex K-theory of the group $\mathbb{Z}_p$ of p-adic integers — based on representing a classifying space $B\mathbb{Z}_p$ as a countable union of inverse limits *or* as an inverse limit of countable unions of compact polyhedra — yield two different answers [W; §6]. According to the interesting computation, $B\mathbb{Z}_p$ is cohomologically infinite-dimensional, but it is this computation that had been only a handwaving until recently. Let us note that there is no contribution from derived limits in either of the two computations.

2) The so-called Čech homology, or *quasi-homology* $qH_n(X)$ of the separable metrizable space X is the inverse limit of the nth homology groups of the nerves of open covers of X (beware that it is not a homology theory in any sense since it is not exact). There is also the *pseudo-homology* $pH_n(X)$, which is the direct limit of the nth quasi-homology groups of compact subsets of X. The natural homomorphism $pH_n(X) \to qH_n(X)$ from the direct limit of inverse limits to the inverse limit of direct limits (of finitely generated groups) is generally neither injective nor surjective for Polish spaces, as shown respectively by P. S. Alexandroff (1947) and E. F. Mishchenko (1953). In fact, we improve their examples to make X locally compact.

3) There is an obvious genuine extension of homology and cohomology to separable metrizable spaces: take the direct limit of homology of compact subsets of X (this is called *Steenrod–Sitnikov homology*) or the direct limit of cohomology of nerves of open covers of X (this is called *Čech cohomology*). In both cases this is a direct limit of refined inverse limits (the refinement takes into account the lim^1 term) of finitely generated groups. (Thus, Steenrod–Sitnikov homology is a "correction" of pseudo-homology.) By going in the opposite order, one obtains the so-called *strong* homology and cohomology — a refined inverse limit (taking into account also the higher lim^k) of direct limits of finitely generated groups. (Thus, strong homology attempts to "correct" Čech quasi-homology.) Weirdly enough, the coincidence of (ordinary) strong homology with Steenrod–Sitnikov homology can be neither proved nor disproved in ZFC for the space as simple as $\mathbb{N}^+ \times \mathbb{N}$ (where $\mathbb{N}$ denotes the infinite countable discrete space, and $+$ denotes the one-point compactification) [MP]. The same can be said of the two kinds of cohomology of the metrizable quotient $\mathbb{N}^+ \times \mathbb{N}/(\{\infty\} \times \mathbb{N})$ (with topology of the quotient uniformity).

It turns out that paradoxes of this sort can be explained, and either exploited to advantage (as with (1) and (2)) or remedied (as with (3)) by means of a more geometric approach to inverse limits based on uniform spaces. The finite-dimensional case of this approach is not hard and long known in essense (Isbell, 1950s); the infinite-dimensional case (which is essential in the context of (1)) is based on a new theory of infinite-dimensional uniform polyhedra [M].

I) The classifying space of a topological group is naturally a uniform space, which is well-defined up to *uniform* homotopy equivalence. This yields a new kind of cohomology for topological groups (other than Lie groups, for which there is nothing new), which can be used to make sense out of Williams' mysterious computation (1).

An application is the following p-adic Borsuk–Ulam theorem: there exists no $\mathbb{Z}_p$-equivariant *uniformly continuous* map from $E\mathbb{Z}_p$ to any compactum with a free action of $\mathbb{Z}_p$. (For instance, to Floyd's 2-dimensional cell-like compactum [W; §5].)

II) In contrast to homology, the analogous homomorphism in cohomology $pH^n(X) \to qH^n(X)$ from the direct limit of inverse limits to the inverse limit of direct limits of finitely generated groups is shown to be surjective for locally compact separable metrizable spaces X, and its kernel is computed to be $lim^1 H^{n-1}(K_i)/lim^1_{fg} H^{n-1}(K_i)$, where the compact subsets K_i exhaust X (so that each $K_i \subset Int K_{i+1}$), and the "tame" derived limit lim^1_{fg} is the direct limit of the lim^1 of inverse sequences of finitely generated subgroups. Here the *quasi-cohomology* $qH^n(X)$ is the inverse limit of the nth cohomology groups of compact subsets of X; and the *pseudo-cohomology* $pH^n(X)$ is the direct limit of the nth quasi-cohomology groups of the nerves of open covers of X.

An application is to embeddability of compacta in Euclidean spaces (a part of this is joint work with E. V. Shchepin). An n-dimensional compactum X embeds in $\mathbb{R}^{2n}$ for $n > 3$ if and only if the van Kampen obstruction $\theta(X) \in H^{2n}(X^*)$ vanishes in Cech cohomology, where $X^* = (X \times X \backslash diagonal)/(\mathbb{Z}/2)$. Next, X quasi-embeds in $\mathbb{R}^{2n}$ for $n > 2$ (i.e., is an inverse limit of compact n-polyhedra that embed there) if and only if the image of $\theta(X)$ in quasi-cohomology $qH^{2n}(X^*)$ vanishes. Finally, X pseudo-embeds in $\mathbb{R}^{2n}$ for $n > 3$ (i.e., is the limit of an inverse sequence of compact n-polyhedra X_i whose finite mapping telescopes $X_{[0,k]}$ admit level-preserving embeddings in $\mathbb{R}^{2n} \times [0,k]$) if and only if the image of $\theta(X)$ in pseudo-cohomology $pH^{2n}(X^*)$ vanishes. Thus the difference between lim^1, lim^1_{fg} and 0 corresponds precisely to the difference between embeddability, pseudo-embeddability and quasi-embeddability. The notion of pseudo-embeddability is interesting because it is equivalent to embeddability when X is a solenoid (i.e., an inverse limit of coverings between polyhedra) and to quasi-embeddability when X is an ANR (here $n > 3$).

III) The definition of strong (co)homology is "wrong" (philosophically — in the sense of Occam's razor), and its "correction" is merely an alternative computation (in ZFC) of the usual (co)homology, at least for Polish spaces. Thus, for instance, the Cech cohomology of a Polish space X can be computed with a spectral sequence of the form $E_2^{pq} = lim^p H^q(K_\lambda) \Rightarrow H^{p+q}(X)$, where the K_λ, $\lambda \in \Lambda$, are nonempty compact subsets of X and the derived limit functors lim^p are "corrected" by taking into account a natural topology on the indexing poset Λ. Namely, when Λ is zero-dimensional (in particular, this applies to $X = \mathbb{N}^+ \times \mathbb{N}/(\{\infty\} \times \mathbb{N})$), the "corrected" derived limits of a diagram G_λ, $\lambda \in \Lambda$, are the homology groups of the cochain complex whose nth term is now not the usual product $\prod_{(\lambda,\lambda_1,\dots,\lambda_{n-1})\in\Lambda^n} G_\lambda$, but its "correction" — the group of all global sections of the natural sheaf with stalks G_λ over the indexing space Λ^n. In the general case, we define the derived limit $lim^p\mathcal{G}$ of the sheaf $\mathcal{G}$ of abelian groups over a partially ordered space Λ as the pth cohomology group of the induced sheaf $\Delta(\mathcal{G})$ over the topological order complex $\Delta(\Lambda)$. Topological order complexes (see [V]) are a special case of the homotopy colimit of a diagram indexed by a continuous category (R. Vogt, 1973).

Incidentally, it is clear from this that the definition of strong shape is also "wrong" for non-compact spaces, and so is the definition of compactly generated strong shape; we will discuss the "correction" for Polish spaces if time permits.

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Coarsely n-to-1 maps

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Coarsely n-to-1 maps are an asymptotic version of maps whose fibers are of cardinality at most n. They are naturally induced by finite group actions on a space. If such action is sufficiently tame then the induced map is a coarse equivalence by the varc-Milnor Lemma. However, a more general action induces a coarsely n-to-1 map which changes the coarse type of a space.

In this talk I will present a number of properties of coarsely n-to-1 maps. These will include their role in the dimension raising theorem and the classification of the asymptotic dimension (a joint work with T. Miyata), the behaviour of the induced maps on the Gromov boundary of a geodesic hyperbolic space (a joint work with J. Dydak), and the impact on property A and recently introduced related invariants (a joint work with J. Dydak and with K. Austin).

Geometric Group Theory

A dense geodesic in reduced Outer Space

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We will prove that there exists a geodesic ray in reduced Outer Space that projects to a dense subset of its quotient by $Out(F_n)$, in fact to the quotient of a certain unit tangent bundle of reduced Outer Space. This is an analogue of a theorem of Masur from 1981, proving the existence of a dense geodesic in the unit tangent space of Moduli space of a closed surface.

Hyperbolic volume, pants decompositions, and Weil-Petersson geometry

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Following work of Schlenker, and inspired by Kojima and Macshane, we recount new developments illustrating new connections between Weil-Petersson geometry and 3-dimensional hyperbolic volume. In particular we give the first explicit lower bounds on systole of moduli spaces of Riemann surfaces with the Weil-Petersson metric in terms of volumes of hyperbolic mapping tori. The results also give explicit upper and lower bounds on Weil-Petersson distances between rational points in the boundary of moduli space in terms of hyperbolic volume and pants distance. This is joint work with Ken Bromberg.

The capacity dimension of the space of ending laminations and the asymptotic dimension of the curve complex

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We give linear bounds, in terms of complexity of the surface, on the two dimensions mentioned in the title.

Amalgam Anosov representations

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We introduce amalgam Anosov representations of an one-ended hyperbolic group into a semi-simple Lie groups and prove that the set of all amalgam Anosov representations forms a domain of discontinuity for the action of the outer automorphism group on the relevant character variety. We show that if the restriction of the representation to each rigid or Fuchsian vertex group of the JSJ-splitting is Anosov, then the representation is amalgam Anosov.

Contracting elements in infinitely presented small cancellation groups

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We study contraction properties of closest point projection to a local geodesic in small cancellation groups.

We construct (many) examples of finitely generated, torsion-free groups in which every element is strongly contracting, but the group is not a subgroup of a hyperbolic group.

Contracting Boundaries: New Developments

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In a recently published paper with Harold Sultan, we introduced a quasi-isometry invariant boundary for CAT(0) spaces, called the contracting boundary. In this talk I will review the basics of that construction and talk about some new developments due to D. Murray and M. Cordes, including dynamical properties of the contracting boundary and a generalization to Morse boundaries for proper geodesic metric spaces.

The boundary of the free splitting graph

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The free splitting graph S has as its vertices the free splittings of the free group F_n and its edges correspond to collapse maps between splittings. S was shown to be hyperbolic by Handel-Mosher. We discuss ongoing work using fold lines in the closure of Culler-Vogtann's Outer space to explore/describe the boundary of S.

Handlebody subgroups in a mapping class group

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Suppose subgroups $A, B < MCG(S)$ are given and let $< A, B >$ be the subgroup they generate. We discuss a question by Minsky asking when $< A, B >= A *_{A \cap B} B$ for handlebody subgroups A, B. We construct an example such that Heegaard distance between A and B is arbitrarily large, $A \cap B$ is trivial but $< A, B >$ is not $A * B$.

Dehn fillings and elementary splittings of groups

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We investigate certain conditions about the (non-)existence of splittings of relatively hyperbolic groups, and how these conditions persist under long Dehn fillings. This implies that certain topological features of the (Bowditch or Gromov) boundary are preserved by long fillings.

Torsion groups acting on CAT(0) cube complexes.

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We construct examples of finitely generated, infinite torsion groups having a *proper* action on an infinite dimensional cube complex. This implies that such a group has the Haagerup property.

Geosphere laminations for the sphere complex

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I will explain how geosphere laminations (introduced by Siddhartha Gadgil and Suhas Pandit) can be useful to investigate the Gromov boundary of the sphere complex.

The Tits alternative for the automorphism group of a free product

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A group G is said to satisfy the Tits alternative if every subgroup of G either contains a nonabelian free subgroup, or is virtually solvable. I will present a version of this alternative for automorphism groups of free products of groups. A classical theorem of Grushko states that every finitely generated group G splits as a free product of the form $G_1 * ... * G_k * F_N$, where F_N is a free group, and all groups G_i are nontrivial, non isomorphic to Z, and freely indecomposable. In this situation, I prove that if all groups G_i and $Out(G_i)$ satisfy the Tits alternative, then so does $Out(G)$. I will give some applications, and present a proof of this theorem, in parallel to a new proof of the Tits alternative for mapping class groups of compact surfaces. The proof relies on the study of the actions of some subgroups of $Out(G)$ on a version of the outer space, and on a hyperbolic simplicial graph.

RAAGs in braids

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We show that every right-angled Artin group (RAAG) embeds into a RAAG defined by the opposite graph of a tree. It follows that an arbitrary RAAG is a quasi-isometrically embedded subgroup of a pure braid group and of the symplectomorphism groups of the disk and the sphere with L^p metrics (for suitable p). This is a joint work with Thomas Koberda.

Extended quotients, Langlands duality and the Baum Connes conjecture for Coxeter groups

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Examining the Baum-Connes conjecture for the (3,3,3) triangle group reveals a relationship between the Baum Connes assembly map and Langlands duality which can be visualised in some simple cases using the extended quotient construction.

Kazhdan projections and random walks

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A Kazhdan projection is a proper projection in the maximal group C*-algebra of a locally compact group that exists if and only if the group has Kazhdan's property (T). Kazhdan projections have applications to K-theory, in particular, they are the source of the currently known counterexamples to various versions of the Baum-Connes conjecture.

The goal of this talk is to present a new construction of Kazhdan projections via random walks. This construction is new in particular in the classical setting of Hilbert spaces, but works in the setting of uniformly convex Banach spaces and has several applications. In particular, we use this construction to answer questions on Banach space versions of property (T), obtain new shrinking target theorems for actions of higher rank groups and construct new examples of ghost projections, which are relevant for higher index theory.

Action Dimension and L^2-homology

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The action dimension of a group G, $\mathrm{actdim}(G)$ is the least dimension of a contractible manifold which admits a proper G-action. The action dimension conjecture states that L^2-homology of any group G vanishes above $\mathrm{actdim}(G)/2$.

I will explain the equivalence of this conjecture to the classical Singer conjecture.

Small subgroups of acylindrically hyperbolic groups

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A subgroup H of a group G is called small if there exists a non-elementary acylindrical action of G on a hyperbolic space such that H has bounded orbits. Examples of small subgroups include proper hyperbolically embedded subgroups, quasi-convex subgroups of infinite index in (relatively) hyperbolic groups, and convex cocompact subgroups of mapping class groups and $Out(F_n)$. We show that many results known in some particular cases can be recovered in this general context.

Balanced walls in random groups

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We study a random group G in the Gromov density model and its Cayley complex X. For density $< 5/24$ we define walls in X that give rise to a nontrivial action of G on a CAT(0) cube complex. This extends a result of Ollivier and Wise, whose walls could be used only for density $< 1/5$. The strategy employed might be potentially extended in future to all densities $< 1/4$.

Rigidity of Teichmüller space

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We study the large scale geometry of Teichmüller space equipped with the Teichmüller metric. We show that, except for low complexity cases, any self quasi-isometry of Teichmüller space is a bounded distance away from an isometry of Teichmüller space.

Boundaries at infinity of Dehn fillings

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In 3-manifold theory, Dehn filling is an important construction of closed hyperbolic manifolds starting from finite-volume ones. There is an algebraic version of such construction in the context of relatively hyperbolic groups that has been used, for example, in the proof of the virtual Haken conjecture. I will describe a method to control the effect of Dehn filling on the boundary at infinity, and present some applications. Based on joint work with D. Groves and J. Manning.

SCL gap for RAAGs

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I will discuss a gap theorem for stable commutator lengths in right-angled Artin groups.

Cycles in moduli spaces of graphs

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Moduli spaces of graphs with a fixed number of loops and leaves are rational classifying spaces for various groups of automorphisms of free groups. These spaces (and therefore the groups) have interesting topology that is not at all well understood. For example, for graphs with no leaves Euler characteristic calculations indicate a huge number of nontrivial homology classes, but only a very few have actually been found. I will discuss the structure of these moduli spaces, including recent progress on the hunt for homology based on joint work with Jim Conant, Allen Hatcher and Martin Kassabov.

Dynamical Systems

On modelling strange attractors on inverse limits of graphs

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Coauthors: Piotr Oprocha

I will discuss the results from [2] where, motivated by [1], we study graph maps that give hereditarily indecomposable inverse limits. We show that positive entropy of such maps imply the existence of an entropy set with infinite topological entropy. This also implies that if f is such a degree 1 circle map then its rotation set is a nondegenerate interval. As a corollary we get that the Anosov-Katok type constructions of the pseudo-circle as a minimal set in volume-preserving smooth dynamical systems, or in complex dynamics, obtained previously by Handel, Herman and Chritat cannot be modeled on inverse limits. This also relates to a result of M. Barge who proved that certain dynamical systems with Hnon-type attractors cannot be modeled on inverse limits.

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Surface dynamics and hyperbolic 3-dimensional geometry

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Thurston's classification theorem for mapping classes and hyperbolization theorem for fibered 3-manifolds establishes a strong connection between the dynamics of surface homeomorphisms and hyperbolic geometry of 3-manifolds. Thurston's theorems deal with finite topology: the surfaces (fibers) considered are compact surfaces minus a finite number of points. In dynamics, however, it is often necessary to consider infinite orbits. In this talk we will discuss an extension of Thurston's hyperbolization to mapping tori associated to generalized pseudo-Anosov homeomorphisms acting on surfaces with infinitely many punctures. We will also discuss connections with the dynamical study of families of interval and plane homeomorphisms.

Braid Equivalence and Renormalization in Dimension Two

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We describe a new mechanism for producing braid equivalences of periodic orbits for diffeomorphisms in dimension two. This mechanism can be shown to yield braid equivalences in the restricted class of Hénon-like diffeomorphisms of the plane. We relate this to the following phenomenon: there are distinct renormalization types for unimodal maps of the interval which are induced by the same Hénon renormalization operator. We then consider some consequences of this last statement, and finish with numerical evidence that these braid equivalences are realised in the Hénon family itself.

On parameter loci of the Hénon family

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Consider the dynamics of the celebrated Hénon family:

$$f_{a,b} : (x, y) \longmapsto (x^2 - a - by, x)$$

defined on $\mathbb{R}^2$. We define the *hyperbolic horseshoe locus*:

$$\mathcal{H}^\times \equiv \{(a, b) \in \mathbb{R} \times \mathbb{R}^\times : f_{a,b} \text{ is a hyperbolic horseshoe on } \mathbb{R}^2\}$$

as well as the *maximal entropy locus*:

$$\mathcal{M}^\times \equiv \{(a, b) \in \mathbb{R} \times \mathbb{R}^\times : f_{a,b} \text{ attains the maximal entropy } \log 2\}.$$

The goal of my talk is to characterize these two loci, namely

Theorem. *There exists an analytic function $a_{\mathrm{tgc}} : \mathbb{R}^\times \to \mathbb{R}$ from the b-axis to the a-axis of the parameter space $\mathbb{R} \times \mathbb{R}^\times$ for the Hénon family $f_{a,b}$ with* $\lim_{b\to 0} a_{\mathrm{tgc}}(b) = 2$ *so that*

(i) $(a, b) \in \mathcal{H}^\times$ *iff* $a > a_{\mathrm{tgc}}(b)$,

(ii) $(a, b) \in \mathcal{M}^\times$ *iff* $a \geq a_{\mathrm{tgc}}(b)$.

Moreover, when $a = a_{\mathrm{tgc}}(b)$, the map $f_{a,b}$ has exactly one orbit of either homoclinic ($b > 0$) or heteroclinic ($b < 0$) tangencies of stable and unstable manifolds of suitable saddle fixed points.

On equivariant homotopy groups of spheres

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Let V be a finite-dimensional orthogonal representation of a compact Lie group G. We denote by S^V a pointed G-sphere obtained by the one-point compactification of V and by S^{k+V} the one-point compactification of $^k \oplus V$, were ^{k} is a trivial representation.

We will be concerned with the following three families of maps.

- $\mathcal{M}_G^*(S^{k+V}, S^V)$ - the space of G-equivariant maps from S^{k+V} into S^V preserving base points;

- $\mathcal{M}_G^{\perp}(S^{k+V}, S^V)$ - the subspace of $\mathcal{M}_G(S^{k+V}, S^V)$ consisting of orthogonal G-maps. We say that $f \in \mathcal{M}_G(S^{k+V}, S^V)$ is *a G-equivariant orthogonal map* if

$$f(x, v) \perp T_v G v$$

for each $(x, v) \in f^{-1}(V) \subset^k \oplus V$.

- $\mathcal{M}_G^{\nabla}(S^{k+V}, S^V)$ - the subspace of $\mathcal{M}_G(S^{k+V}, S^V)$ consisting of gradient G-maps.

Relations between gradient and nongradient equivariant homotopy groups of spheres will be discussed. To this purpose we will consider the auxiliary class of orthogonal equivariant maps. That class is in some sense natural enlargement of the class of gradient equivariant maps. We will give a description of the stable equivariant homotopy groups of spheres in the category of orthogonal maps in terms of classical stable equivariant groups of spheres with shifted stems. We conjecture that stable equivariant homotopy groups of spheres for orthogonal maps and for gradient maps are isomorphic. The concept of *otopy* , introduced by Becker and Gottlieb in [1], provides a convenient framework for simultanous proof of results in all three categories of mappings (see [3]).

[1] J.C. Becker, D.H. Gottlieb *Vector fields and transfers*, Manuscripta Math., 72 (1991), 111-130.

[2] M.C. Crabb, I. James *Fiberwise Homotopy Theory*, Springer-Verlag London Ltd., 1998.

[3] K. Geba, M. Izydorek *On relations between gradient and classical homotopy groups of spheres*, J. Fixed Point Theory Appl. 12, no 1-2, (2012), 49-58.

Connecting Orbits for a Class of Singular Planar Newtonian Systems

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We will consider a planar Newtonian system $q''+\nabla V(q) = 0$ with a potential $V : \mathbb{R}^2 \setminus \{\xi\} \to \mathbb{R}$ possessing a singularity at a point ξ: $V(x) \to -\infty$ as $x \to \xi$, and a strict global maximum 0 that is achieved at two distinct points a and b in $\mathbb{R}^2 \setminus \{\xi\}$. Applying a variational approach we will establish the existence of homoclinic and heteroclinic solutions winding around ξ provided that nearby the singularity the potential V satisfies a strong force condition.

Horseshoes in generalized inverse limits

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Suppose $f : I \to 2^I$ is a upper semicontinuous bonding map. Let $M = \{(x_0, x_1...) : x_{i-1} \in f(x_i) \text{ for } i > 0\}$. Even though f is not even a function in the usual sense, it induces a continuous function σ from M onto M. The function σ is called the shift map on M, since for $\mathbf{x} = (x_0, x_1, ...) \in M$, $\sigma(\mathbf{x}) = \sigma(x_0, x_1, ...) = (x_1, x_2, ...)$. M is called an inverse limit on set-valued functions, or, equivalently, a generalized inverse limit. These objects were introduced in 2003 by W. Mahavier, and they present a new method of understanding the dynamical behavior of set-valued functions.

While much work by many researchers has been done on understanding the topology of these spaces, we are just beginning a study of the dynamical properties exhibited by the shift map σ. Horseshoes arise naturally in these inverse limits under very mild conditions. We will discuss our findings.

Measure preserving aperiodic dynamical systems

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There are many examples of aperiodic dynamical systems on closed three dimensional manifolds, but few are measure preserving. We will discuss the difficulties in obtaining aperiodic, smooth, measure preserving dynamical systems on S^3 and measure preserving nonsingular dynamical systems on R^3 with uniformly bounded orbits.

Dynamically defined pseudometrics and the construction of generic points

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Generic points are dynamical analogs of normal numbers. Ergodic Theorem guarantees that every ergodic invariant measure of a dynamical system has a generic point, but this is not necessarily true for non-ergodic measures. I am going to discuss conditions, which imply that every invariant measure has a generic point. These conditions generalize various notions of specification and lead to a construction of explicit examples of numbers normal to non-integer bases in the spirit of Champernowne. Dynamically defined Besicovitch and Weyl pseudometrics play an important role in our investigations.

Counting preimages

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For a transitive piecewise monotone interval map one of the ways to compute its entropy is to find the exponential growth rate of the number of preimages of a point under iterates of the map. However, looking for all preimages takes too much computer memory and time. One of the ideas used in similar situations (for instance, for Iterated Function Systems or rational holomorphic maps) is to replace the tree of all preimages of a point by one randomly chosen branch. We iterate the following procedure: given a point, we note the number of its preimages under the map and choose the next point randomly from those preimages. It turns out that this process is governed by a special measure, which we call *fair measure*, and instead of the topological entropy we get the entropy of this measure.

Shadowing of pseudo-orbits: partial and complete

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A δ-pseudo orbit in a dynamical system (X, T) is a sequence satisfying $d(T(x_i), x_{i+1}) < \delta$ for all $i \in I \subset \mathbb{N}$ (and some $\delta > 0$), while shadowing means that every δ-pseudo orbit can be ε-shadowed by a point $z \in X$, that is $d(T^i(z), x_i) < \varepsilon$ for all $i \in J \subset \mathbb{N}$ (and clearly δ depends on ε). In the classical definition of shadowing we demand $I = J = \mathbb{N}$, however recently there appeared in the literature concepts of shadowing, where I, J are from a specified class of subsets of integers. In that sense we can speak about "partial" shadowing. At one hand, when $I \neq \mathbb{N}$, we can combine blocks of pseudo-orbits which gives us lots of freedom. On the other hand, we do not know exact segments where tracing takes place.

In this talk we will survey recent results on relations between "partial" and "complete" shadowing. Surprisingly, for some choices of classes of sets $I, J \subset \mathbb{N}$ these connections are quite tight.

Dynamical systems with Lipschitz shadowing: the role of smoothness

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It was shown in [1] that a diffeomorphism of a smooth closed manifold having the Lipschitz shadowing property is structurally stable.

In this talk, we discuss the proof of this result.

We also show that there exists a homeomorphism of the segment having the Lipschitz shadowing property and a nonisolated fixed point (thus, its dynamics is completely different from that of a structurally stable diffeomorphism).

[1] S. Yu. Pilyugin and S. B. Tikhomirov. Lipschitz shadowing implies structural stability, *Nonlinearity*, **23**, 2509-2515 (2010).

Dynamical zeta functions and symmetric products

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Let X be an ENR, $U \subset X$ be an open set and $f : U \to X$ be a continuous map. The fixed point indices of the iterates of f in U, when well defined, provide valuable information about the set of periodic orbits of f. The computation of that sequence is an important and usually very difficult problem. We shall adopt an alternative point of view. We will study the fixed point indices of the induced maps in the n-symmetric products of X, $i(SP_n(f), SP_n(U))$, discuss its main properties and encode all of them in the formal serie $SP_\infty(f, U) = \sum_{n\geq 0} i(SP_n(f), SP_n(U))z^n$.

From an axiomatic approach and a uniqueness theorem it follows that $SP_\infty(f, U)$ coincides with the dynamical zeta function obtained from the indices of the iterates of f.

Obtaining information about isolated invariant sets in terms of their isolating blocks

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We consider isolated invariant sets K in 3–manifolds. In Conley index theory one does not study these sets directly, but rather in terms of their so-called isolating neighbourhoods N. In applications, these neighbourhoods are frequently computable, unlike the invariant sets themselves, so it is natural to wonder how much information about K can be gleaned from N. In this talk we shall consider two instances of this problem: given an isolating block N, (i) what can be said about the Betti numbers of K? and (ii) assuming it is known that K is an invariant loop (for instance, a periodic orbit), what can be said about its knottedness?

Non-saddle sets, bifurcations and Morse decompositions

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We study the general structure of a flow on a manifold having a non-saddle set. We examine, in particular, the role of dissonant points and analyze the existence of these points in the case of flows on surfaces. We prove that bifurcations consisting of implosions of the basin of attraction of an attracting point produce non-saddle sets of spherical shape. We characterize non-saddle sets of Morse decompositions in terms of topological properties of their duals. These results have been obtained in collaboration with Héctor Barge.

Lozi mappings and symbolic dynamics

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In 1978 Lozi introduced a two-parameter family of piecewise linear homeomorphisms of the plane which may give rise to very complicated chaotic dynamics and strange attractors. In 1997 Ishii coded the Lozi strange attractors by bi-infinite sequences of two symbols, which are called itineraries (of points of attractor). He proved that the Lozi map restricted to its strange attractor is topologically conjugate to the shift homeomorphism restricted to the corresponding symbol space, the space of all itineraries. I will show necessary and sufficient conditions, in terms of kneading sequences, that a bi-infinite sequence of two symbols be an itinerary of a point of the Lozi attractor, and discuss some applications and interesting questions which arise from that result.

Forcing theory for transverse trajectories of surface homeomorphisms and applications

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We develop a new theory of orbit forcing for homeomorphisms of surfaces in the isotopy class of the identity and we present some applications. In particular, we extend Franks and Handel's classification of entropy zero maps of the sphere to nonwandering homeomorphisms, showing that such maps have an almost integrable behaviour, and also a Handel result for transitive maps of S^2. We also show that any homeomorphism of the open annullus which satisfies the

Birkhoff instability condition and whose rotation set has two different points must have positive topological entropy.

Arithmetical coding and tiling dynamics

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The idea of an aritmetical coding of a hyperbolic toral automorphism began with Thurston (1989 AMS Colloquium Lectures) and has been considerably developed by Kenyon, Schmidt, Vershik, Sidorov, and others; it can be summarized as follows. Given a Pisot unit $\beta > 1$ of algebraic degree d, let (X_β, σ) be the β-shift, let M be the companion matrix of the minimal polynomial of β, and let $F_M : \mathbb{T}^d \to \mathbb{T}^d$ be the corresponding hyperbolic toral automorphism. An *aritmetical coding* of F_M (the terminology is due to Sidorov) is a continuous, bounded-to-one, surjection $h : X_\beta \to \mathbb{T}^d$ with the properties:
(i) If x and y are non-negative real numbers having β -expansions $\underline{x}$ and $\underline{y}$, then $h(\underline{x+y}) = h(\underline{x}) + h(\underline{y})$; and
(ii) $h \circ \sigma = F_M \circ h$.

Such codings always exist and it is conjectured that, in fact, there is always an almost everywhere one-to-one arithmetical coding. We will sketch a proof of the following:
Theorem: If $\beta > 1$ is a Pisot unit, and also a *simple Parry number* (meaning that there is $k \in \mathbb{N}$ with $T_\beta^k(1) = 0$, where $T_\beta(x) := \beta x - \lfloor \beta x \rfloor$), then there is an a.e. 1-1 aritmetical coding of the associated hyperbolic toral automorphism.

The proof routes through the following recent result for substitution tiling systems:
Theorem: If ϕ is primitive substitution on the alphabet $\mathcal{A}$, with Pisot inflation, for which there are $n \in \mathbb{N}$ and $b \in \mathcal{A}$ so that $\phi^n(a) = a \cdots b$ for all $a \in \mathcal{A}$, then the tiling dynamical system $(\Omega_\phi, \mathbb{R})$ has pure discrete spectrum.

Contributed Talks

On the role of universal G-spaces of R. Palais in the conjecture of J. West and H. Torunczyk

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When we shift the accent in studying of compact transformation groups from G-spaces to their orbit projections, there arises the natural point of view on G-spaces as generalized principal fibrations. (Thus, the restriction of the orbit projection on each orbit bundle of given type is reduced to principal fibrations.) When acting accordingly to such approach, it is natural to wonder about the G-spaces that correspond to the universal principal fibrations. Answering this question R. Palais introduced the notion of the universal G-space (though he had restricted himself to finite-dimensional G-spaces with finite collection of orbit types), and with its help he extended the classical theorem on classification of fibrations for the equivariant category G-TOP. However, in doing so the structure of universal G-spaces was not investigated in details (in particular, the question whether the restriction of orbit projection on each its orbit bundle of given type is intimately connected with an universal principal fibration was not answered).

The progress in the investigation of universal G-spaces was made recently (in what follows we will use another term – isovariant extansors). (See the papers [2] and [3] containing the progress in the theory of universal G-spaces.) It turns out that these objects may shed additional light on many questions. Thus, the properties of universal $\mathcal{F}$-spaces in the sense of T. Dieck are fully unveiled within the isovariant extensor theory. Several objects of geometry, topology and analysis are endowed in natural manner with extra structure of isovariant extansors, that sometimes permits to make decisive step in the study of their properties (for example, Banach-Mazur compacta). It is very plausible hypothesis that classifying G-spaces of some equivariant homotopy functors are in fact isovariant neighborhood extensors. When applied to the equivariant K-functor this means that the space of Fredholm operators on the complex Hilbert G-space is an isovariant neighborhood extensor, and the general linear group on the complex Hilbert G-space is an isovariant extensor.

The aim of our report is a discussion of these and some others questions on isovariant extensors. The part of them gets a positive solution. The question on exponent exp(G) of connected compact Lie group G is among them.

Investigating $\exp(S^1)$ J. West and H. Torunczyk displayed an interesting structure connected with Eilenberg-MacLane complexes in the orbit space (remark that they used essentially one-dimensional arguments and their method can not be generalized to more interesting Lie groups). Apparently, the initial aim of their research was the conjecture that for each connected compact Lie group G, exp(G) is the equivariant Hilbert cube with unique fixed point. We prove that this conjecture is reduced to isovariant extensors:

Theorem 1. Let G be a connected compact Lie group. If exp(G) is an isovariant extensor, then exp(G) is the equivariant Hilbert cube with unique fixed point.

Theorem 2. Let G=SO(n) be a connected orthogonal group. Then exp(G) is an isovariant extensor and therefore exp(G) is the equivariant Hilbert cube with unique fixed point.

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Detecting (weak) fractals among Peano continua

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A compact metric space X is called a (weak) fractal if $X = f_1(X) \cup \cdots \cup f_n(X)$ for some (weakly) contracting maps $f_1, \dots, f_n : X \to X$.

A self-map $f : X \to X$ of a metric space (X, d) is called *contracting* if it is Lipschitz with Lipschitz constant < 1, and f is weakly contracting if $d(f(x), f(y)) < d(x, y)$ for any distinct points $x, y \in X$.

We shall discuss the following open problem posed by Hata in 1985:

Problem. Is each Peano continuum homeomorphic to a weak fractal?

The following theorem (whose partial case for $n = 1$ was proved by Dumitru in 2012) gives a partial answer to this problem of Hata.

Theorem. A Peano continuus is homeomorphic to a weak fractal if it contains an open subset homeomorphic to $\mathbf{R}^n$ for some $n > 0$.

This theorem is completed by the following characterization:

Theorem. For a Peano continuum X containing an open subset homeomorphic to the interval $(0, 1)$ the following conditions are equivalent:

- X is homeomorphic to a fractal;
- X has finite S-dimension $S - \dim(X)$;
- X has finite Hölder dimension $H\ddot{o} - \dim(X)$.

The S-dimension S-dim and Hölder dimension $H\ddot{o}$-dim were introduced in [BT] and used in [BN] (for constructing a one-dimensional Peano continuum, which is not homeomorphic to a fractal).

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Unstable manifold, Conley index and applications to planar flows

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The unstable manifold of an isolated invariant compactum is a complicated topological object which carries an important amount of dynamical information. Although in the general situation the flow restricted to the unstable manifold is not parallelizable, we shall see that a mild form of parallelizability is fulfilled. From this fact many nice consequences are derived, specially in the case of plane continua. For instance, an easy method of calculation of the Conley index involving some knowledge of the topology of the unstable manifold, and as a consequence, a relation between the Brouwer degree and the unstable manifold is established for smooth vector fields. All the results presented in this talk have been obtained in collaboration with J.M.R Sanjurjo.

Divergent sequences of quasi-Fuchsian representations

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Consider a sequence of quasi-Fuchsian representations of a finitely generated group acting on the three-dimensional hyperbolic space. If the sequence goes to infinity, there's an isometric action of the group on a -tree for which it converges. This compactification, due to Morgan-Shalen / Bestvina / Paulin, is a key step in Otal's proof of Thurston's hyperbolization of fibered 3-manifolds. In this talk I'll discuss an extension of the compactification for infinitely generated groups that arises puncturing generalized pseudo-Anosov homeomorphisms of surfaces. This is a joint work in progress with Andr de Carvalho.

Continuity of coarse shape groups

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The coarse shape groups are algebraical invariants in the homotopy and the (coarse) shape theory, as well. Their structure is significantly richer than the structure of homotopy and shape groups. In this talk we give an explicit formula for computing coarse shape groups for a large class of metric compacta including solenoids. We show that every coarse shape group can be obtained as the inverse limit of an inverse system of groups. It is proven that, for inverse systems of compact polyhedra, the coarse shape group functor commutes with the inverse limit.

Hyperbolic volume of links, via pants graph and train tracks

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A result of Jeffrey Brock states that, given a hyperbolic 3-manifold which is a mapping torus over a surface S, its volume can be expressed in terms of the distance induced by the monodromy map in the pants graph of S. This is an abstract graph whose vertices are pants decompositions of S, and edges correspond to some 'elementary alterations' of those. Brock's theorem motivates investigation about distances in the pants graph; in particular we generalise a result of Masur, Mosher and Schleimer that train track splitting sequences induce quasi-geodesics in the marking graph. This will be the core piece of a volume estimate for complements of closed braids in the solid torus.

Gropes and crumpled cubes

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Recently Daverman and Gu have introduced a hierarchy for crumpled n-cubes. We present some examples of crumpled 3-cubes based on generalizations of Alexander's Horned Sphere and show some relations.

Combinatorial modulus on boundaries of some right-angled hyperbolic buildings

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It is known since G.D. Mostow that the quasi-conformal structure of the boundary of a hyperbolic space can be used to obtain rigidity results. In the case of right-angled buildings of dimension 2, the Loewner property is a key tool to prove the rigidity of quasi-isometries. Hence a natural question to ask is: do some boundaries of buildings of dimension 3 carry the Loewner property?

The combinatorial Loewner property is a discrete version of the Loewner property that is conjecturally equivalent to it. Yet this second property seems easier to find on the boundary of a hyperbolic group as it do not require the knowledge of the conformal dimension.

In my talk I will investigate the quasi-conformal structure of some right-angled hyperbolic buildings of dimension 3 thanks to combinatorial tools. As a result I will present some buildings whose boundaries satisfy the combinatorial Loewner property.

On the geometry of the flip graph

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The flip graph of an orientable punctured surface is the graph whose vertices are the ideal triangulations of the surface and whose vertices are joined by an edge if the two corresponding triangulations differ by a flip. The combinatorics of this graph is crucial in works of Thurston and Penner's decorated Teichmuller theory. In this talk we will explore some geometric properties of this graph, in particular we will see that it provides a coarse model of the mapping class group in which the mapping class groups of the subsurfaces are convex. Moreover, we will provide upper and lower bounds on the growth of the diameter of the flip graph modulo the mapping class group. Joint work with Hugo Parlier (Universite de Fribourg).

Axiomatization of geometry employing group actions and topology

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The aim of the talk is to outline a new axiomatization of planar geometry by reinterpreting the original axioms of Euclid. The basic concept is still that of a line segment but its equivalent notion of betweenness is viewed as a topological, not a metric concept. That leads quickly to the notion of connectedness without any need to dwell on the definition of topology. In our approach line segments must be connected. Lines and planes are unified via the concept of separation: lines are separated into two components by each point, planes contain lines that separate them into two components as well. We add a subgroup of bijections preserving line segments and establishing unique isomorphism of basic geometrical sets, and the axiomatic structure is complete. Of fundamental importance is the Fixed Point Theorem that allows for creation of the concepts of length and congruency of line segments.

The resulting structure is much more in sync with modern science than other axiomatic approaches to planar geometry. For instance, it leads naturally to the Erlangen Program in geometry. Our Conditions of Homogeneity and Rigidity have two interpretations. In physics, they correspond to the basic tenet that independent observers should arrive at the same measurement and are related to boosts in special relativity. In geometry, they mean uniqueness of congruence for certain geometrical figures.

Euclid implicitly assumes the concepts of length and angle measure in his axioms. Our approach is to let both of them emerge from axioms. Euclid obfuscates the fact that to compare lengths of line segments one needs rigid motions beforehand. Our system of axioms of planar geometry rectifies that defect of all current axiomatic approaches to planar geometry (of Hilbert and Tarski).

Another thread of the talk is the introduction of boundary at infinity, an important concept of modern mathematics, and linking of Pasch Axiom to endowing boundaries at infinity with a natural relation of betweenness. That way spherical geometry can be viewed as geometry of boundaries at infinity.

Mahavier product and topological entropy

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We introduce new definition of topological entropy, which is given in terms of a new tool, the Mahavier product which was introduced by Judy Kennedy and Sina Greenwood.

Suppose that X, Y and Z are topological spaces, and $A \subset X \times Y$, $B \subset Y \times Z$. Then we define the Mahavier product of A and B as set $\{(x, y, z) \in X \times Y \times Z : (x, y) \in A \text{ and } (y, z) \in B\}$.

We calculate topological entropy using covers of Mahavier product.

By using the entropy of the shift map (a function in the usual sense) it is shown that this generalization of the notion of entropy has many of the same properties as those for entropy in regular functions. We will show the entropy of some new ones and some well-known examples.

Morse geodesics in lacunary hyperbolic groups

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A geodesic is Morse if quasi-geodesics connecting points on it stay uniformly close. If the embedding of the cyclic subgroup generated by an element is a Morse geodesic, then that element is called a Morse element. In many known examples, Morse geodesics in groups have been found via Morse elements. By studying asymptotic cones and using small cancellation, we will show how Morse geodesics can be exhibited in many lacunary hyperbolic groups, including Tarski monsters. This represents first examples of groups that have Morse geodesics but no Morse elements. I will describe further properties of non-Morse geodesics and also show how a tree can be quasi-isometrically embedded into such groups.

A topological dimension like-function of the type dim

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We introduce a dimension like-function for topological spaces, denoted by $\dim_q$, using the classical covering dimension dim. Basic properties of $\dim_q$, examples, and questions are given.

The primitivity index function for a free group, and untangling closed curves on surfaces

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A theorem of Scott shows that any closed geodesic on a surface lifts to an embedded loop in a finite cover. Our motivation is to find a worst-case lower bound for the degree of this cover, in terms of the length of the original loop. Using probabilistic methods we establish lower bounds for certain analogous functions, like the Primitivity Index Function and the Simplicity Index Function, in a free group. These lower bounds, when applied in a suitable way to the surface case, give us some lower bounds for our motivating question. This is joint work with Ilya Kapovich. (arXiv:1411.5523)

Mapping the harmonic archipelago

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The study of wild algebraic topology has in the last decade seen an increased interest in spaces of dimension two or higher where nontrivial loops can be homotoped arbitrarily close to a point. The harmonic archipelago is a standard example with this property. The space is homeomorphic to a disc but for a single point and can be described as the reduced suspension of the graph of the topologist's sine curve y = sin(1/x).

The fundamental group of this space has peculiar mapping properties. For example, every countable locally free group embeds in G as a subgroup (hence so does the fundamental group of the complement of Alexander's horned cell!). In turn, every separable profinite group is an epimorphic image, as is every cotorsion group of at most continuum cardinality.

There is a Bounded Non Convex set S, in the Union of all Euclidean Spaces E, that has the Unique Nearest Point Property and T, the Closure of S in the Completion of E, does not have the Unique Nearest Point Property

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E is the union of all Euclidean spaces and H is the separable Hilbert space that is the completion of E. Bunt in 1934 showed that if a set in a Euclidean space has the unique nearest point property, then it is closed and convex. Klee asked in 1951 if this was also true in Hilbert space. In 1984 it was shown that there is a bounded non convex set S in E that has the property that each point in E has a unique nearest point in S. We shall show that T, the closure of S in H, does not have the property that each point in H has a unique nearest point in T.

Linear isometries of continuous function spaces

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For a compact Hausdorff space X, $C(X)$ denotes the Banach space of all complex-valued continuous functions with the supremum norm. The classical Banach-Stone theorem states that each complex-linear surjective isometry $T : C(X) \to C(Y)$ of $C(X)$ onto $C(Y)$ is a weighted composition operator with a unimodular weight, in other words, there exists a homeomorphism $h : Y \to X$ and a continuous function $\alpha : Y \to \mathbb{C}$ with $|\alpha| \equiv 1$ such that $Tf(y) = \alpha(y) \cdot f(h(y))$ for each $f \in C(X)$ and for each $y \in Y$. When T is real-linear, the conclusion still holds with "a unimodular weighted composition operator" being replaced by "a unimodular weighted composition operator, its complex-conjugate, and their combination." Such isometry is said to take the canonical form. Banach-Stone type theorems hold for many linear subspaces of continuous functions, while there exists a real-linear isometry $S : A \to A$ of non-canonical form defined on a complex-linear subspace A of $C(\mathbb{T})$, the continuous functions of the circle $\mathbb{T}$. In this talk we discuss topological conditions on a compact Hausdorff space X which imply that every linear isometry between subspaces of $C(X)$ is of the canonical form. Also a sytematic construction of non-canonical isometry will be given when the underlying space admits a semi-free action of $\mathbb{T}$ with a global section. Extensions to Banach space-valued function spaces are discussed. This is a joint work with Takeshi Miura, Niigata Univesity.

A class of topological spaces between the classes of regular and Urysohn spaces

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We define and investigate the rU-spaces. A space X is said to be a rU-space if X is a Hausdorff space and for every $x \in X$ and every open neighbourhood V of x there exists an open neighbourhood U of x such that $U \subseteq \mathrm{Cl}(V)$ and $\mathrm{Bd}(U) \subseteq V$. The class of rU-spaces is properly placed between the classes of regular and Urysohn spaces.

Devaney's chaos in general semiflows

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We will talk about sensitivity, syndetic sensitivity and Devaney's chaos in general abelian semiflows. We give some conditions for a semiflow which imply syndetic sensitivity even with a restricted acting monoid.

Higson corona and fixed points

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It is known that a quasi-isometriy on a proper metric space has a homeomorphic extension on its Higson corona. In this talk, we consider a condition of spaces (or maps) to induce the fixed point free homeomorphism on the corona. It is also considered that when the fixed points set on the corona is expressed as the accumulation points of a closed subset of the underlying space.

Equivalence of intrinsic strong shape and external strong shape

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In the paper [2] the authors showed that their strong shape category of metric compacta is isomorphic to the categories of Yu. Lisica, and of J.B. Quigley, and therefore coincides with strong shape theories for metric compacta by D. A. Edwards and H. M. Hastings, F. W. Bauer, Y. Kodama and J. Ono, J. Dydak and J. Segal, F. W. Catney and Z. R. Miminovili. In the paper will be shown the equivalence of Intrinsic strong shape from [2] and External strong shape from [1]. References: [1] Yu. Lisica, S. Mardešić, Coherent homotopy and strong shape for compact metric spaces, Glasnik Mat. Vol. 20(40) (1985), 159-167 [2] N.Shekutkovski, Intrinsic definition of strong shape for compact metric spaces, Topology Proceedinds 39 (2012), 27-39

When Outer Space behaves like Teichmuller space (or hyperbolic spaces) & how we can use this to understand $Out(F_r)$

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$Out(F_r)$ is one of the most intriguing groups to study because of its natural action on a space, Culler-Vogtmann Outer Space, which both strongly resembles and intricately differs from some of the most well-known and studied spaces, such as Teichmuller space and hyperbolic spaces. In this talk I will present several dynamical results about when Outer Space behaves like these other spaces and explain how we have used them to help understand $Out(F_r)$. This is joint work with Yael Algom-Kfir, Ilya Kapovich, and Lee Mosher.

The Quotient Shapes - a new perspective to shape

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For every category C and each infinite cardinal k, there exists a pair of shape categories Ck-, Ck determined by all the objects having cardinality less than k, less or equal to k, respectively. The idea is to consider the quotient objects by equivalence relations that are compatible with the structures and morphisms. The application to the well known concrete categories C: partially ordered sets, pseudometric spaces, topological spaces, monoids, groups, rings, modules, vector spaces, ..., gives rise to intersting examples, especially to the k-- shape and k-shape classifications of C-objects.

Asymptotic property C of the countable sum of integers

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The notion of asymptotic property C is introduced by Dranishnikov (2000) as a coarse analogue of Haver's property C in topological dimension theory. In 2013, Dranishnikov and Zarichnyi asked whether the countable direct sum of integers has asymptotic property C. In this talk, we consider the question.

Milnor-Thurston homology theory for wild spaces

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In the algebraic topology of manifolds and CW-complexes the computation of homology groups is often regarded to be just a standard exercise in diagram chase. For more "wild" spaces, this is usually not the case. The Mayer-Vietoris Theorem is not valid without local conditions that are usually not fulfilled by such spaces, and the homology groups are not longer determined by the Eilenberg-Steenrod Axioms any longer; and therefore the computation of homology groups becomes usually a non-trivial task, often also requiring methods of geometric topology, e.g. surgery techniques to those maps which can represent cycles. Geometric topology has also the power to explain some of the results, that are commonly interpreted that way that the behaviour of singular homology groups on wild spaces must sometimes be regarded to be anomalous ([MB], [EK1, Thm.3.1], the fact that there is no standard formula for the shrinking wedge [EK2] vs. [EKRZ, Thm.1.6]). There have also propositions been made to create new homology theories with the idea of better behaving on wild spaces. ([DiSpr], [Grg]). However, the main goal of the talk will not be to create a new homology theory, but to report on a research project ([Prz], [PZ]) of the past four years that has been testing an existing homology theory, to what extent it is suitable for being applied to wild spaces. This homology theory ("Milnor-Thurston homology theory") was proposed by Thurston giving a part of the credit to Milnor, for having a certain application in the theory of hyperbolic manifolds. It is based on the idea of replacing the classical finite chains of singular homology theory by measures of sets of singular simplices. Since a good deal of the above quoted anomaly-results have its origin in the fact that the classical algebraical invariants are built on a finite arithmetic while the structure of wild spaces could often only be mimicked by an infinite arithmetic, and measures are kinds of infinite sums, the idea to test this homology theory on wild spaces arose. The so far computed Milnor-Thurston homology groups were in some cases unexpected, but in all cases as discussed so far, geometric topology could explain what is going on.

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Hernndez Paradigm for the asymptotic dimension of locally compact abelian groups

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Let G be a locally compact abelian group and let G^+ denote the same group equipped with the Bohr topology (namely the topology induced on G by its Bohr compactification). We discuss the asymptotic dimension of G and G^+ and, extending a theorem of S. Hernández on the covering dimension, we prove that $\operatorname{asdim} G = \operatorname{asdim} G^+$. According to a recent result of A. Nicas and D. Rosenthal, this equality can be extended to $\operatorname{asdim} G^+ = \operatorname{asdim} G = \dim G$, where G denotes the Pontryagin dual of G.

Special Lecture

Flatness and Local Flatness of $(n-1)$-spheres in S^n

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This workshop talk will review classical results, due to Morton Brown, about embeddings of the $(n-1)$-sphere in S^n. An embedded sphere is said to be *flat* if it is ambiently equivalent to the standart one. Brown's striking results are (1) that bicollared spheres are flat and (2) that locally flat spheres are bicollared. (A sphere Σ is *bicollared* if there exists an embedding of $S^{n-1} \times [-1, 1] \to S^n$ with Σ being the image of $S^{n-1} \times 0$.)

Dynamic Asymptotic Dimension

by

Rufus Willett,

University of Hawaii

Coauthors: Erik Guentner and Guoliang Yu

I'll introduce a notion of 'dynamic asymptotic dimension' (d.a.d.), which is a translation of Gromov's asymptotic dimension from coarse geometry and geometric group theory into topological dynamics. I'll describe some motivating examples, and the relationship with asymptotic dimension and some other notions of dimension. I'll then sketch applications to Novikov and Baum-Connes type conjectures using controlled K-theory, inspired partly by earlier work of Farrell-Jones, Yu, and Bartels-Lück-Reich.

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