6-26-2017

# Conference Program

University of Dayton

# 32ND SUMMER CONFERENCE ON TOPOLOGY AND ITS APPLICATIONS

UNIVERSITY of DAYTON

## Tuesday, June 27 - Friday, June 30, 2017

## Invited Speakers

**Ian Biringer,** Boston College
**Jan Boronski,** AGH Krakow & IT4Innovations Ostrava
**Dikran Dikranjan,** Udine University
**Isabel Garrido,** Universidad Complutense Madrid
**Helge Glockner,** Paderborn University
**Eriko Hironaka,** Florida State
**Karl H. Hofmann,** Technische Universitaet Darmstadt and Tulane University
**Jen Hom,** Georgia Tech
**Jean Lafont,** The Ohio State University
**Olga Lukina,** University of Illinois, Chicago
**Kathryn Mann,** University of California, Berkeley (2016 Mary Ellen Rudin Award winner)
**Paul McKenney,** Miami University, Ohio
**Michael Mislove,** Tulane University
**Ted Porter,** Murray State University
**Janusz Prajs,** California State University, Sacramento
**Tom Richmond,** Western Kentucky University
**Reynaldo Rojas-Hernandez,** Universidad Nacional Autónoma de México
**Walter Tholen,** York University
**Vladimir Tkachuk,** Universidad Autonoma Metropolita

## Session Organizers

**Topology + Algebra & Analysis,** Salvador Hernandez, Gabor Lukacs, and Frederic Mynard
**Topology + Asymmetric Structure,** Michael Bukatin, Ralph Kopperman and Olivier Olela Otafudu
**Topology + Dynamics & Continuum Theory,** Lori Alvin and Jonathan Meddaugh
**Topology + Foundations,** Alan Dow and John (Ted) Porter
**Topology + Geometry,** Pallavi Dani and Max Forester

## Scientific Committee

**Natalie Frank,** Vassar College
**Gary Gruenhage,** Auburn University
**Ralph Kopperman,** The City College of New York
**Krystyna Kuperberg,** Auburn University
**Vladimir Tkachuk,** Universidad Autónoma Metropolitana

## Organizing Committee

**Jon Brown,** University of Dayton
**Joe Mashburn,** University of Dayton
**Vicki Withrow,** University of Dayton
**Lynne Yengulalp,** University of Dayton

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# 32nd Summer Conference on Topology and its Applications

University of Dayton
Dayton, Ohio, USA

June 27–30, 2017

**Wi-Fi instructions:** Go to your Wi-Fi connection settings on your device and choose "UDwireless." In the pop-up window, find the "Visitors: Connect to UDwireless" section and click on "Register for guest network access." Follow the prompts to set-up your temporary account. You will receive a network password good for 16 hours that is renewable up to four times.

# Schedule

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<tr><td>10:00 - 10:30</td><td>Break (Rm 124)</td><td>Break (Rm 124)</td><td>Break (Rm 124)</td><td>Break (Rm 124)</td></tr>
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<tr><td>12:30 - 1:00</td><td rowspan="2">Lunch</td><td rowspan="3">Lunch</td></tr>
<tr><td>1:00 - 1:30</td></tr>
<tr><td>1:30 - 2:00</td><td rowspan="2">Tom Richmond (Rm 119)<br>Isabel Garrido (Rm 201)<br>Janusz Prajs (Rm 103)</td><td rowspan="2">(P)Kathryn Mann<br>Rm 119</td><td rowspan="2">Bus pick-up S2 Lot<br>Airforce museum (1:30 PM)</td></tr>
<tr><td>2:00 - 2:30</td><td rowspan="2">(P) Jean Lafont<br>Rm 119</td></tr>
<tr><td>2:30 - 3:00</td><td rowspan="2">(W) Dikran Dikranjan<br>(Rm 214)<br>(W) Ted Porter (Rm 119)</td><td rowspan="2">(W) Dikran Dikranjan<br>(Rm 214)<br>(W) Ted Porter (Rm 119)</td><td rowspan="6"></td></tr>
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**Registration** Miriam Hall Atrium, Room 124.

**Plenary talks** O'Leary Hall, Room 119.

**Workshops** Porter, Room 119; Dikrajan, Room 214.

**Topology + Algebra & Analysis** Room 213.

**Topology + Asymmetric Structures** Room 205.

**Topology + Dynamics & Continuum Theory** Room 103 (Room 104).

**Topology + Foundations** Room 214 (Room 201).

**Topology + Geometry** Room 109.

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|---|---|---|---|---|---|
| | | | | | |
| **Tuesday** | Room 213 | **Wednesday** | Room 213 | **Friday** | Room 213 |
| 10:30 - 11:00 | Neil Hindman | 10:30 - 11:00 | Rafael Dahmen | 11:30 - 12:00 | |
| 11:00 - 11:30 | Maxim R. Burke | 11:00 - 11:30 | Gábor Lukács | 12:00 - 12:30 | |
| 11:30 - 12:00 | Dariusz Bugajewski | 11:30 - 12:00 | Daniele Toller | | |
| | | | | 4:30 - 5:00 | |
| 4:00 - 4:30 | Xiao Chang | 4:00 - 4:30 | TMG Ahsanullah | 5:00 - 5:30 | |
| 4:30 - 5:00 | Menachem Shlossberg | 4:30 - 5:00 | Salvador Hernández | 5:30 - 6:00 | |
| 5:00 - 5:30 | Luis Tárrega | 5:00 - 5:30 | J. O. Olaleru | | |

| Topology + Asymmetric Structures | | | Room 205 | | |
|---|---|---|---|---|---|
| | | | | | |
| **Tuesday** | Room 205 | **Wednesday** | Room 205 | **Friday** | Room 205 |
| 10:30 - 11:00 | *Walter Tholen | 10:30 - 11:00 | Seminar | 11:30 - 12:00 | *Michael Mislove |
| 11:00 - 11:30 | *Walter Tholen | 11:00 - 11:30 | Ralph Kopperman | 12:00 - 12:30 | *Michael Mislove |
| 11:30 - 12:00 | Tom Vroegrijk | 11:30 - 12:00 | Seminar | | |
| | | | | 4:30 - 5:00 | Stephen Rodabaugh |
| 4:00 - 4:30 | *Tom Richmond | 4:00 - 4:30 | Seminar | 5:00 - 5:30 | Stephen Rodabaugh |
| 4:30 - 5:00 | *Tom Richmond | 4:30 - 5:00 | Collins Amburo Agyingi | 5:30 - 6:00 | Olela Otafudu |
| 5:00 - 5:30 | Seminar | 5:00 - 5:30 | Hope Sabao | | |

*Session slots are reserved following plenary and semi-plenary speakers for discussion.

| Topology + Dynamics and Continuum Theory | Rooms 103 and 104 | | | | | |
|---|---|---|---|---|---|---|
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| **Tuesday** | Room 103 | **Wednesday** | Room 103 | Room 104 | **Friday** | Room 103 |
| 10:30 - 11:00 | Jennyffer Bohorquez | 10:30 - 11:00 | John C Mayer | | 11:30 - 12:00 | Lori Alvin |
| 11:00 - 11:30 | David Cosper | 11:00 - 11:30 | Joanna Furno | | 12:00 - 12:30 | Ramon Barral Lijo |
| 11:30 - 12:00 | James Kelly | 11:30 - 12:00 | Judy Kennedy | | | |
| | | | | | 4:30 - 5:00 | Felix Capulin Perez |
| 4:00 - 4:30 | Sergio Macias | 4:00 - 4:30 | Daniel Ingebretson | Mathew Timm | 5:00 - 5:30 | Miguel A. Lara |
| 4:30 - 5:00 | David Maya | 4:30 - 5:00 | Krystyna Kuperberg | Paul Gartside | 5:30 - 6:00 | |
| 5:00 - 5:30 | Gabriele Carcassi | 5:00 - 5:30 | Jesús A. Álvarez López | Max Pitz | | |

| Topology + Foundations | Rooms 214 and 201 | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Tuesday** | Room 214 | Room 201 | **Wednesday** | Room 214 | Room 201 | **Friday** | Room 214 |
| 10:30 - 11:00 | Alan Dow | | 10:30 - 11:00 | Jila Niknejad | Vladimer Baladze | 11:30 - 12:00 | Nathan Carlson |
| 11:00 - 11:30 | Alex Shibakov | | 11:00 - 11:30 | Joe Mashburn | Leonard Mdzinarishvili | 12:00 - 12:30 | Ivan S. Gotchev |
| 11:30 - 12:00 | Akira Iwasa | | 11:30 - 12:00 | David Guerrero Sánchez | Anzor Beridze | | |
| | | | | | | 4:30 - 5:00 | Daniel Hathaway |
| 4:00 - 4:30 | Jocelyn Bell | Fr.V. ANTONY SAMY | 4:00 - 4:30 | Strashimir G. Popvassilev | Çetin Vural | 5:00 - 5:30 | Sergei Logunov |
| 4:30 - 5:00 | Hector Alonzo Barriga Acosta | M.Y. Bakier | 4:30 - 5:00 | Jerry E. Vaughan | Bhamini M. P. Nayar | 5:30 - 6:00 | Joshua Sack |
| 5:00 - 5:30 | Piotr Szewczak | Ramandeep Kaur | 5:00 - 5:30 | Joan Hart | Ruslan Tsinaridze | | |

| | | | | | |
|---|---|---|---|---|---|
| **Topology + Geometry** | | Room 109 | | | |
| | | | | | |
| **Tuesday** | Room 109 | **Wednesday** | Room 109 | **Friday** | Room 109 |
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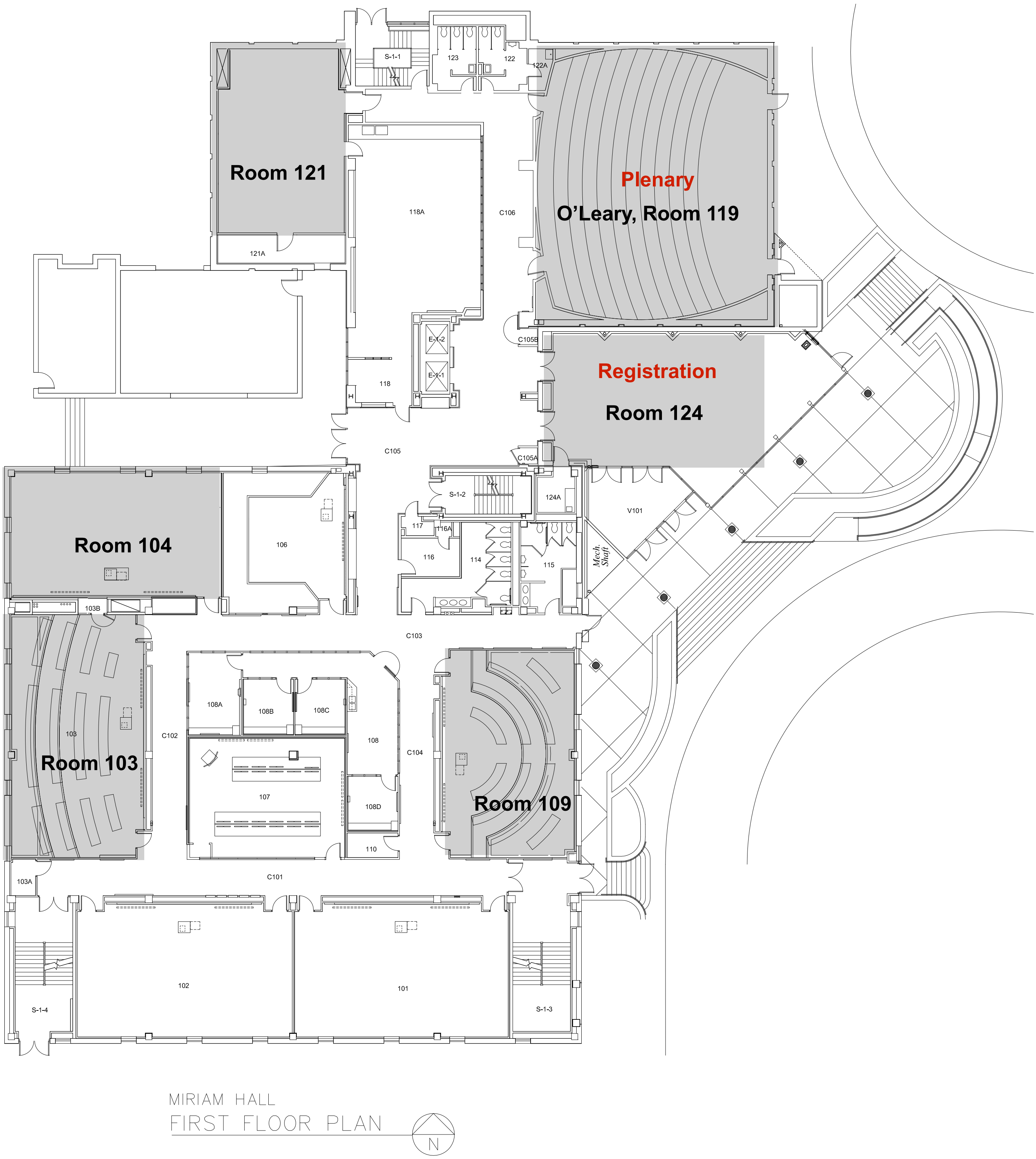
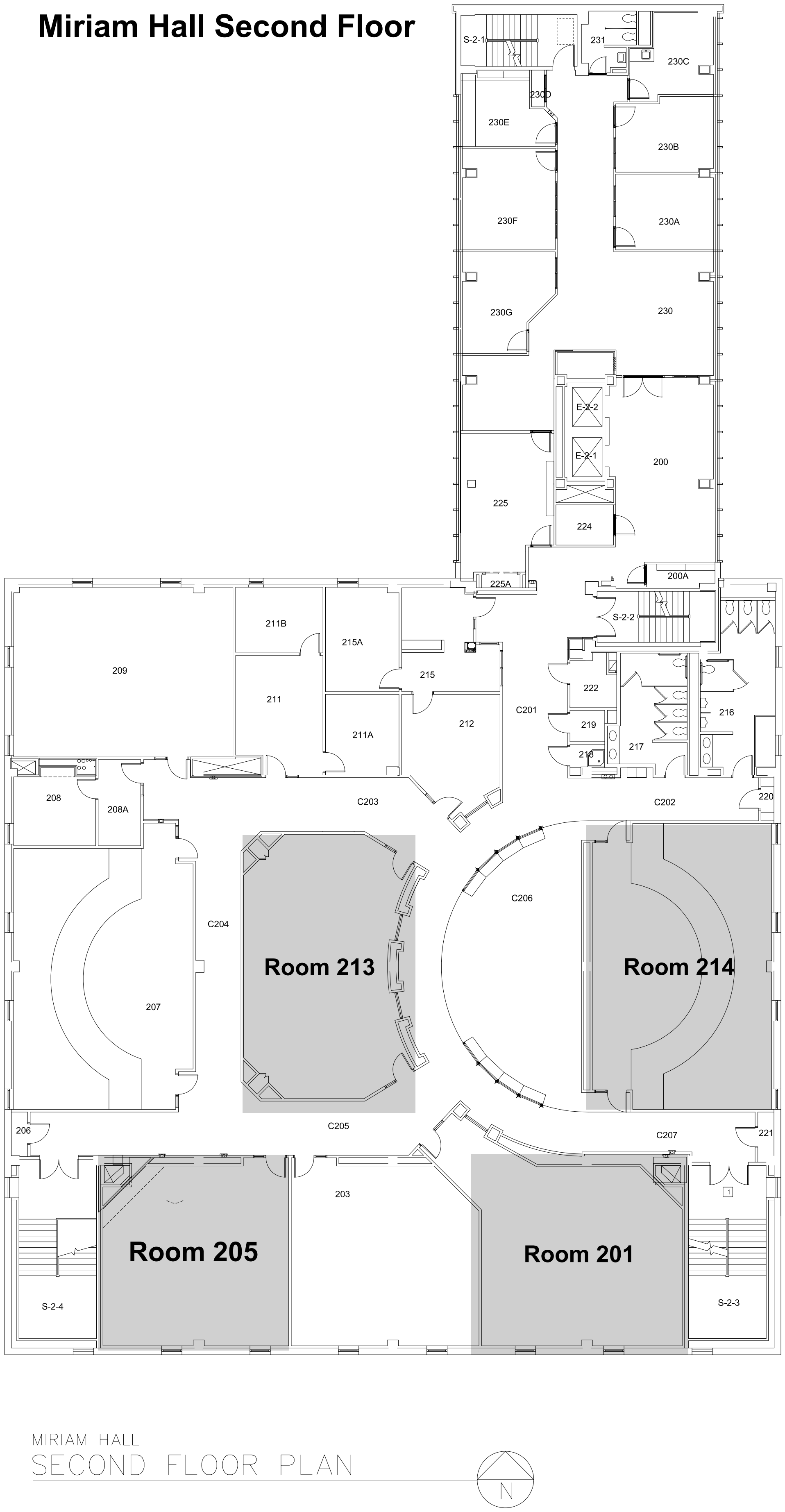
| 11:00 - 11:30 | Chris O'Donnell | 11:00 - 11:30 | Elmas Irmak | 12:00 - 12:30 | Shi Wang |
| 11:30 - 12:00 | Sean Cleary | 11:30 - 12:00 | Greg Bell | | |
| | | | | 4:30 - 5:00 | Thomas Weighill |
| 4:00 - 4:30 | Eduardo Martinez Pedroza | 4:00 - 4:30 | Kevin Schreve | 5:00 - 5:30 | Micah Chrisman |
| 4:30 - 5:00 | Andrew Sale | 4:30 - 5:00 | Tommaso Cremaschi | 5:30 - 6:00 | Andrzej Nagorko |
| 5:00 - 5:30 | Ignat Soroko | 5:00 - 5:30 | Benjamin Linowitz | | |

# Miriam Hall First Floor



# Miriam Hall Second Floor




MIRIAM HALL
SECOND FLOOR PLAN

# 32nd Summer Conference on Topology and its Applications

University of Dayton
Dayton, Ohio, USA

June 27–30, 2017

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# Workshops

**Entropy in Topological Groups, Room 214**

Dikran Dikranjan
*Udine University*
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Entropy was introduced first in thermodynamics and statistical mechanics, as well as information theory. In the last sixty years entropy made its way also in topology, ergodic theory, as well as other branches of mathematics as algebra, geometry and number theory where dynamical systems appear in one way or another.

Roughly speaking, entropy is a non-negative real number or infinity assigned to a "selfmap" T of a "space" X, where the "space" X can be a topological or uniform space, a measure space, an abstract or topological group (or vector space) or just a set. The "selfmap" T can be, respectively, a (uniformly) continuous selfmap, a measure preserving transformation, a (continuous) endomorphism, etc. Depending on each choice, one may have a topological entropy, uniform entropy, measure entropy, algebraic entropy, etc.

We intend to discuss:

(a) the connection between these entropies with particular emphasis on the case of topological groups;

(b) a unified (categorical) approach to entropy based on appropriate functors to the category of normed semigroups;

(c) the connection of entropy to other well-known functions (e.g., the scale function of Georege Willis, the Mahler measure and the related Lehmer problem in number theory, etc);

(d) (if time permits) entropy of semigroup actions (in place of selfmaps).

**References**

R. Adler, A. Konheim, M. McAndrew, Topological entropy, Trans. Amer. Math. Soc. 114 (1965) 309-319

D. Dikranjan, A. Giordano Bruno, Entropy on abelian groups, Adv. Math. 298 (2016) 612-653

D. Dikranjan, B. Goldsmith, L. Salce and P. Zanardo, Algebraic entropy of endomorphisms of abelian groups, Trans. Amer. Math. Soc. 361 (2009), 3401-3434

D. Dikranjan, M. Sanchis, S. Virili, New and old facts about entropy in uniform spaces and topological groups, Topology Appl. 159 (2012) 1916-1942

A. Giordano Bruno, S. Virili: Topological entropy in totally disconnected locally compact groups, Ergodic Theory and Dynamical Systems (2016) doi:10.1017/etds.2015.139

K.H. Hofmann, L. Stoyanov, Topological entropy of group and semigroup actions. Adv. Math. 115 (1995) no. 1, 54-98

J. Peters, Entropy on discrete abelian groups, Adv. Math. 33 (1979) 1-13

**Workshop on Monotone Covering Properties, Room 119**

Ted Porter
*Murray State University*
jporter@murraystate.edu

Topological properties, when monotonized, have proven to be useful and interesting. The past couple of decades has seen a growth in the study of monotone covering properties. For the purpose of this workshop, a monotone covering property of a topological space $X$ is an operator $r : \mathcal{A} \subset \mathcal{C} \to \mathcal{C}$ (where $\mathcal{C}$ is the set of open covers of $X$) such that (1) $r(\mathcal{U})$ is a suitable refinement of $\mathcal{U}$ for every $\mathcal{U} \in \mathcal{A}$, and (2) if $\mathcal{U}, \mathcal{V} \in \mathcal{A}$ and $\mathcal{U}$ refines $\mathcal{V}$, then $r(\mathcal{U})$ refines $r(\mathcal{V})$. For example, a topological space is said to be monotonically Lindelöf (compact) if $r(\mathcal{U})$ is countable (finite) for every $\mathcal{U} \in \mathcal{C}$ or monotonically countably metacompact if $r(\mathcal{U})$ is point-finite and $\mathcal{A}$ is the set of all countable open covers of $X$.

Monotone versions of covering properties often behave differently than their non-monotonized versions. Different characterizations of paracompact spaces, when monotonized, may give rise to different classes of spaces. Monotonically Lindelöf spaces may not even be monotonically countably metacompact. I will also discuss metrization theorems, open problems, and further areas of research on monotone covering properties.

# Plenary Speakers

**A compact minimal space whose Cartesian square is not minimal, Room 119**

Jan P. Boronski
*AGH Krakow and IT4Innovations Ostrava*
jan.boronski@osu.cz
Coauthors: Alex Clark and Piotr Oprocha

A compact metric space $X$ is called *minimal* if it admits a minimal homeomorphism; i.e. a homeomorphism $h : X \to X$ such that the forward orbit $\{h^n(x) : n = 1, 2, \ldots\}$ is dense in $X$, for every $x \in X$. In my talk I shall outline a construction of a family of 1-dimensional minimal spaces from [1], whose existence answer the following long standing problem in the negative.

**Problem.** *Is minimality preserved under Cartesian product in the class of compact spaces?*

Note that for the fixed point property this question had been resolved in the negative already 50 years ago by Lopez [3], and a similar counterexample does not exist for flows, as shown by Dirbák [2].

**References**

[1] Boronski J.P.; Clark A.; Oprocha P., *A compact minimal space Y such that its square YxY is not minimal.* arXiv:1612.09179

[2] Dirbák, M. *Minimal extensions of flows with amenable acting groups.* Israel J. Math. **207** (2015), no. 2, 581–615.

[3] Lopez, W. *An example in the fixed point theory of polyhedra.* Bull. Amer. Math. Soc. **73** 1967 922–924.

**Locally Compact Groups: Tradition and Trends, Room 119**

Karl Heinrich Hofmann
*Technische Universitt Darmstadt and Tulane University, New Orleans*
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Coauthors: W. Herfort, F.G.Russo

For a lecture in the Topology+Algebra+Analysis section, the subject of locally compact groups appears particularly fitting: Historically and currently as well, the structure and representation theory of locally compact groups draws its methods from each of theses three fields of mathematics. Nowadays one might justifiably add Combinatorics +Number Theory as sources.

The example of a study of a class of locally compact groups called “near abelian”, undertaken by W.Herfort, K.H.Hofmann, and F.G.Russo, may be used to illustrate the liaison of topological group theory with this different areas of interest. Concepts like the compact Hausdorff “Chabauty space” attached to each locally compact group, or the “scalar multiplication” of periodic locally compact abelian groups can serve as guiding moments in contemplating this diversity. (03-21-2017)

W.Herfort, K.H.Hofmann, and F.G.Russo, Near Abelian Locally compact Groups, Preprint 2017, ix+228pp.

**Knot surgery and Heegaard Floer homology, Room 119**

Jennifer Hom
*Georgia Tech*
hom@math.gatech.edu
Coauthors: Cagri Karakurt, Tye Lidman

One way to construct new 3-manifolds is by surgery on a knot in the 3-sphere; that is, we remove a neighborhood of a knot, and reglue it in a different way. What 3-manifolds can be obtained in this manner? We provide obstructions using the Heegaard Floer homology package of Ozsvath and Szabo. This is joint work with Cagri Karakurt and Tye Lidman.

**Hyperbolic groups with boundary an n-dimensional Sierpinski space, Room 119**

Jean-Francois Lafont
*The Ohio State University*
jlafont@math.ohio-state.edu
Coauthors: Bena Tshishiku, Harvard

Gromov hyperbolicity is a "large-scale" version of negative curvature. A finitely generated group is called hyperbolic if it has a Cayley graph which is Gromov hyperbolic. Such a group has a well-defined boundary at infinity, a topological space which encodes the different directions along which you can escape to infinity. We will consider groups G whose boundary at infinity is an n-dimensional Sierpinski space. If n is at least 5, we will show that any such group can be realized as the fundamental group of an aspherical manifold of dimension n+2, with non-empty boundary. We will also briefly explain why the converse fails. This was joint work with Bena Tshishiku (Harvard)

**Orders on groups and actions on 1-manifolds, Room 119**

Kathryn Mann
*University of California, Berkeley*
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Given a group G, and a manifold M, can one describe all the ways that G acts on M? More precisely, can one parameterize the space of actions of G on M? This is a remarkably rich question even in the case where M is the line or the circle, and is connected to problems in topology, foliation theory, and dynamics.

This talk will describe one very useful way to capture such an action, namely, through the algebraic data of a left-invariant linear or circular order on a group. I'll explain new work, joint with C. Rivas, that relates the topology of the space of orders on a group G to the moduli space of actions of G on the line or circle. As an application we'll see new rigidity phenomena for actions, and the answers to some older questions about orderings.

**Order, distance, closure and convergence: reconciling competing fundamental topological concepts, Room 119**

Walter Tholen
*Dept. of Mathematics and Statistics, York University, Toronto*
`tholen@mathstat.yorku.ca`

Already in Hausdorff's 1914 book [H], often considered the cradle of general topology, one finds traces of a discussion on the relative strengths of the concepts mentioned in the title of this talk. In fact, one may argue that Hausdorff anticipated the basic ideas of how to unify these concepts, which were developed only later on by many mathematicians over the course of a century, as propagated in the recent book [HST]. Indeed, Hausdorff thought of ordering points by assigning to every pair of them a (truth) value, just as a metric assigns to them a number. More importantly, he also contemplated extending such assignments to pairs, whose second component would remain a point, but whose first component would now be a subset, or a sequence, of points of the space in question, which is then assigned a value that measures the extent to which that point lies in the closure of the subset, or is a convergence point of the sequence. In monoidal topology, the first components of the arguments of such value assignments are given by a monad $T$ on **Set** (where, for a set $X$, $TX$ could be all strings of points of $X$, or all subsets of $X$, or all filters on $X$, etc), while the values themselves must lie in a quantale $V$ (which could be the lattice $2 = \{\text{true}, \text{false}\}$, or the non-negative extended real line, or the lattice of distribution functions of that extended line, etc). These structures must then satisfy two basic axioms, generalizing the reflexivity and transitivity of relations. With morphisms to be maps laxly preserving the structure, this defines the category $(T, V)$-**Cat**, which is topological over **Set** and, therefore, automatically boosts a wealth of good properties.

The principal categories of interest to topologists are all of this type, or may be reflectively or coreflectively embedded into them. But as indicated above, an individual category, like **Top**, may be presentable in various $(T, V)$-guises, and establishing the equivalence may not necessarily be easy. In fact, its validity may depend on additional properties of $V$. For example, for $T$ the powerset monad, we may easily extend the usual properties of distance and closure to define and study so-called $V$-topological spaces, but the establishment of their equivalent description in terms of a $V$-valued ultrafilter convergence relation requires $V$ to be completely distributive (see [LT]). Among other theorems, we will present this equivalence statement and show how it unifies previous results for topological spaces and approach spaces and leads to novel applications. Time permitting we will also discuss essential topological properties, like compactness and separation, in the $V$-context.

**References**

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[HST] D. Hofmann, G.J. Seal, W. Tholen (eds): *Monoidal Topology*, Cambridge Univ. Press, Cambridge 2014.

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**Dense subsets of function spaces with no non-trivial convergent sequences, Room 119**

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We will show that a monolithic compact space $X$ is not scattered if and only if $C_p(X)$ has a dense subset without non-trivial convergent sequences. Besides, for any cardinal $\kappa \geq \mathfrak{c}$, the space $\mathbb{R}^\kappa$ has a dense subspace without non-trivial convergent sequences. If $X$ is an uncountable $\sigma$-compact space of countable weight, then any dense set $Y \subset C_p(X)$ has a dense subspace without non-trivial convergent sequences. We also prove that for any countably compact sequential space $X$, if $C_p(X)$ has a dense $k$-subspace, then $X$ is scattered.

## Semi-plenary Speakers

**Unimodular measures on the space of all Riemannian manifolds, Room 109**

Ian Biringer
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Coauthors: Miklos Abert, Jean Raimbault

We will discuss 'unimodular' measures on the space of all pointed Riemannian manifolds (M,p). These measures can be described in different ways: through a conservation of mass formula, via transverse measures on foliated spaces, or as measures that (when lifted to the space of unit tangent bundles of Riemannian manifolds) are invariant under geodesic flow. Unimodular measures are useful since many sequence of finite volume manifolds have subsequences that converge in some sense to a such a measure. In other words, one can use these measures to compactify spaces of finite volume manifolds, much like one uses measured laminations to compactify the set of simple closed curves on a surface. We will mention an application to higher rank locally symmetric spaces, and will describe how to understand the topology of unimodular measures supported on surfaces with bounded curvature.

**Some topics around Uniformly Continuous Functions, Room 201**

Isabel Garrido
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In this talk we will present some recent results where the uniformly continuous functions on metric (or uniform) spaces play an important role. Namely, results about approximation by uniformly continuous functions, algebraic properties of the family of real-valued uniformly continuous functions, new notions of realcompactifications, and new properties of completions.

Most of these results have been obtained in collaboration with G. Beer (California State University, Los Angeles) and A.S. Meroño (Universidad Complutense de Madrid, Spain).

**Completeness of infinite-dimensional Lie groups in their left uniform structure, Room 201**

Helge Glöckner
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I'll explain that many of the main examples of infinite-dimensional Lie groups are complete in their left uniform structure. The findings are based on results concerning the completeness of strict direct limits of complete topological groups, small box products, and topological groups which are locally $k_\omega$.

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**Braid group actions on rational maps, Room 103**

Eriko Hironaka
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Coauthors: Sarah Koch

Rational maps are maps from the Riemann sphere to itself that are defined by ratios of polynomials. A special type of rational map is the ones where the forward orbit of the critical points is finite. That is, under iteration, the critical points all eventually cycle in some periodic orbit. In the 1980s Thurston proved the surprising result that (except for a well-understood set of exceptions) when the post-critical set is finite the rational map is determined by the "combinatorics" of how the map behaves on the post-critical set. Recently, there has been interest in the question: what happens if we just fix the degree and impose the condition that only one critical orbit is finite. In that case, the family of rational maps defined by the combinatorics is a complex manifold naturally acted on by subgroups of the pure spherical braid group on n-strands where n depends on the order of the orbit and the degree, In this talk, we discuss the question: what is the global topology of this manifold? The work is joint with Sarah Koch.

**Classifying matchbox manifolds, Room 103**

Olga Lukina
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A matchbox manifold is a compact connected foliated space, locally homeomorphic to the product of a Euclidean disk and a Cantor set. Strange attractors in dynamical systems, and exceptional minimal sets of smooth foliations present examples of matchbox manifolds. Many actions of profinite groups on trees can be suspended to obtain matchbox manifolds, and similar examples arise in other contexts and in other parts of mathematics.

Thus there is a natural problem of classifying matchbox manifolds. The most tractable class of matchbox manifolds is the class of weak solenoids which are the inverse limits of finite-to-one coverings of closed manifolds. In my talk, I will describe the recent results in this direction, obtained by my co-authors and myself. This includes the asymptotic discriminant, an algebraic invariant which can be seen as the measure of local complexity of matchbox manifolds.

**Rigidity and nonrigidity of corona algebras, Room 214**

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Coauthors: Alessandro Vignati

Shelah proved in the 70's that there is a model of ZFC in which every homeomorphism of the Cech-Stone remainder of the natural numbers is induced by a function on the natural numbers. More recently, Farah proved that in essentially the same model, every automorphism of the Calkin algebra on a separable Hilbert space must be induced by a linear operator on the Hilbert space. I will discuss a common generalization of these rigidity results to a certain class of C*-algebras called corona algebras. No prerequisites in C*-algebra will be assumed.

**Domains and Probability Measures: A Topological Perspective, Room 119**

Michael Mislove
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Domain theory has seen success as a semantic model for high-level programming languages, having devised a range of constructs to support various effects that arise in programming. One of the most interesting - and problematic - is probabilistic choice, which traditionally has been modeled using a domain-theoretic rendering of sub-probability measures as valuations. In this talk, I will place the domain-theoretic approach in context, by showing how it relates to the more traditional approaches such as functional analysis and set theory. In particular, we show how the topologies that arise in the classic approaches relate to the domain-theoretic rendering. We also describe some recent developments that extend the domain approach to stochastic process theory.

**Isometrically Homogeneous Continua, Topologically Homogeneous Continua and the Pseudo-arc, Room 103**

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We use accumulated knowledge on topologically homogeneous continua, and, in particular, on the pseudo-arc, to investigate the properties of isometrically homogeneous continua.

**Topology and Order, Room 119**

Tom Richmond
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We will discuss topologies as orders, orders on sets of topologies, and topologies on ordered sets. More specifically, we will discuss Alexandroff topologies as quasiorders, the lattice of topologies on a finite set, and partially ordered topological spaces. Some topological properties of Alexandroff spaces are characterized in terms of their order. Complementation in the lattice of topologies on a set and in the lattice of convex topologies on a partially ordered set will be discussed.

**On the Lindelöf $\Sigma$-property and some related conclusions, Room 214**

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We will present some known and some new results about Lindelöf $\Sigma$-spaces. We extend some classical results about the Lindelöf and the Lindelöf $\Sigma$-property in spaces $C_p(X)$ for compact $X$ to the case when $X$ is a Lindelöf $\Sigma$-space. We also present some results about the Lindelöf $\Sigma$-property in $\Sigma_s$-products. A result of Tkachenko is generalized by showing that the bound $w(X) \leq nw(X)^{Nag(X)}$ holds for regular (not necessarily Tychonoff) spaces. Finally we present the solution for two question posed by V. V. Tkachuk about Eberlein and Corson compact spaces.

# Topology + Algebra and Analysis

**Quantale-valued gauge groups and approach convergence transformation groups, Room 213**

TMG Ahsanullah
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E. Colebunders, et al., introduced a category $\mathbf{C}$ [3], consisting of objects all triple $(X, S, \delta)$, where $X \in |\mathbf{CAP}|$, an object in the category of Lowen-approach spaces [8], $S \in |\mathbf{CAG}|$, an object in the category of approach groups [9], and $\delta\colon X \times S \longrightarrow X$, a contraction mapping. Actually, in [3], the authors brought to light a concept of approach convergence *transformation* monoids without explicit mention. On the other hand, following the idea of probabilistic convergence group [1] (see also [5]), we introduced a category of probabilistic convergence transformation groups, **PCONVTG** [2]. Our motive here is to demonstrate the link between these two categories. In so doing and, failing to provide a direct link between these two, apparently different approaches, we consider a *value quantale* $\mathbb{V}$ in the line of [6,7] (see also [4], with opposite order), and propose a notion of quantale-valued gauge group (en route to a category $\mathbb{V}$-**CONVTG**) - a notion closely related to quantale-valued metric group vis-à-vis quantale-valued convergence group. The advantage that we have using $\mathbb{V}$-**CONVTG** is, it provides a global framework, where $\mathbf{C}$, like many others existing categories of similar nature, serve examples whenever appropriate quantales are considered.

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**On a construction of some class of metric spaces, Room 213**

Dariusz Bugajewski
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In this talk we are going to describe Száz's construction of some class of metric spaces. Most of all we will analyze topological properties of metric spaces obtained by using Száz's construction. In particular, we provide necessary and sufficient conditions for completeness of metric spaces obtained in this way. Moreover, we will discuss the relation between Száz's construction and the "linking construction". A particular attention will be drawn to the "floor" metric, the analysis of which provides some interesting observations.

**Generic approximation and interpolation by entire functions via restriction of the values of the derivatives, Room 213**

Maxim R. Burke
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A theorem of Hoischen states that given a positive continuous function $\varepsilon : \mathbb{R}^n \to \mathbb{R}$, an unbounded sequence $0 \leq c_1 \leq c_2 \leq \ldots$ and a closed discrete set $T \subseteq \mathbb{R}^n$, any $C^\infty$ function $g : \mathbb{R}^n \to \mathbb{R}$ can be approximated by an entire function $f$ so that for $k = 0, 1, 2, \ldots$, for all $x \in \mathbb{R}^n$ such that $|x| \geq c_k$, and for each multi-index $\alpha$ such that $|\alpha| \leq k$,

(a) $|(D^\alpha f)(x) - (D^\alpha g)(x)| < \varepsilon(x)$;

(b) $(D^\alpha f)(x) = (D^\alpha g)(x)$ if $x \in T$.

We show that if $C \subseteq \mathbb{R}^{n+1}$ is meager, $A \subseteq \mathbb{R}^n$ is countable and disjoint from $T$, and for each multi-index $\alpha$ and $p \in A$ we are given a countable dense set $A_{p,\alpha} \subseteq \mathbb{R}$, then we can require also that

(c) $(D^\alpha f)(p) \in A_{p,\alpha}$ for $p \in A$ and $\alpha$ any multi-index;

(d) if $x \notin T$, $q = (D^\alpha f)(x)$ and there are values of $p \in A$ arbitrarily close to $x$ for which $q \in A_{p,\alpha}$, then there are values of $p \in A$ arbitrarily close to $x$ for which $q = (D^\alpha f)(p)$;

(e) for each $\alpha$, $\{x \in \mathbb{R}^n : (x, (D^\alpha f)(x)) \in C\}$ is meager in $\mathbb{R}^n$.

Clause (d) is a surjectivity property which can be strengthened to allow for finding solutions in $A$ to equations of the form $q = h^*(x, (D^\alpha f)(x))$ under similar assumptions, where $h(x, y) = (x, h^*(x, y))$ is one of countably many given fiber-preserving homeomorphisms of open subsets of $\mathbb{R}^{n+1} \cong \mathbb{R}^n \times \mathbb{R}$.

We also prove a weaker corresponding result with "meager" replaced by "Lebesgue null." In this context, the approximating function is $C^\infty$ rather than entire, and we do not know whether it can be taken to be entire.

**Which topological groups arise as automorphism groups of locally finite graphs? Room 213**

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Coauthors: Paul M Gartside

Let $\Gamma$ be a graph which is countable and locally finite (every vertex has finite degree). Then the automorphism group of $\Gamma$, $\mathrm{Aut}(\Gamma)$, with the pointwise topology has a compact, zero dimensional open normal subgroup. We investigate whether the converse holds.

### Compactly supported homeomorphisms as long direct limits, Room 213

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Coauthors: Gabor Lukacs

Let $\lambda$ be a limit ordinal and consider a directed system of topological groups $(G_\alpha)_{\alpha<\lambda}$ with topological embeddings as bonding maps and its directed union $G = \bigcup_{\alpha<\lambda} G_\alpha$. There are two natural topologies on $G$: one that makes $G$ the direct limit (colimit) in the category of topological spaces and one which makes $G$ the direct limit (colimit) in the category of topological groups.

For $\lambda = \omega$ it is known that these topologies almost never coincide (*Yamasaki's Theorem* [1]).

In my talk last year, I introduced the *Long Direct Limit Conjecture*, stating that for $\lambda = \omega_1$ the two topologies always coincide.

This year, I will introduce one particular example of such a direct limit: The groups of compactly supported homeomorphisms of the Long Line which is naturally such a directed union of topological groups. I will explain why on this group the two direct limit topologies mentioned above agree (and are equal to the compact open topology). Unfortunately this method only works in dimension one and breaks down as soon as one wants to consider groups of homeomorphisms of the Long Plane or similar two dimensional manifolds.

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### Groups with few finite dimensional representations, Room 213

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Suppose an algebraic group $G$ is equipped with two locally compact topologies $G_1 = (G, \tau_1)$ and $G_2 = (G, \tau_2)$. In case $G$ is abelian,we have that $G_1$ and $G_2$ are naturally (topologically) isomorphic if and only if so are their respective Bohr compactifications $bG_1$ and $bG_2$. Furthermore, if $\tau_1 \subsetneq \tau_2$, then $|\frac{bG_2}{bG_1}| \geq 2^{\mathfrak{c}}$. Therefore the Bohr compactification of a locally compact abelian group completely characterizes its topological and algebraic structure. It is known that this fact do not extend to non abelian groups and basically every option is possible for these groups. In this talk, we will discuss to what extent the Bohr compactification of a non abelian locally compact group reflects its topological and algebraic structure.

### Topological properties of some algebraically defined subsets of $\beta\mathbb{N}$, Room 213

Neil Hindman
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Coauthors: Dona Strauss, University of Leeds

Let $S$ be a discrete semigroup and let the Stone-Čech compactification $\beta S$ of $S$ have the operation extending that of $S$ which makes $\beta S$ a right topological semigroup with $S$ contained in its topological center. We show that the closure of the set of multiplicative idempotents in $\beta\mathbb{N}$ does not meet the set of additive idempotents in $\beta\mathbb{N}$. We also show that the following algebraically defined subsets of $(\beta\mathbb{N}, +)$ are not Borel: the set of idempotents; the smallest ideal; any semiprincipal right ideal of $\mathbb{N}^*$; the set of idempotents in any left ideal; and $\mathbb{N}^* + \mathbb{N}^*$.

**On the tightness and long directed limits of free topological algebras, Room 213**

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For a limit ordinal $\lambda$, let $(A_\alpha)_{\alpha<\lambda}$ be a system of topological algebras (e.g., groups or vector spaces) with bonding maps that are embeddings of topological algebras, and put $A = \bigcup_{\alpha<\lambda} A_\alpha$. Let $(A, \mathcal{T})$ and $(A, \mathcal{A})$ denote the direct limit (colimit) of the system in the category of topological spaces and topological algebras, respectively. One always has $\mathcal{T} \supseteq \mathcal{A}$, but the inclusion may be strict; however, if the tightness of $\mathcal{A}$ is smaller than the cofinality of $\lambda$, then $\mathcal{A} = \mathcal{T}$.

In this talk, we show that the free abelian topological group $A(\omega_1)$ and the free topological vector space $V(\omega_1)$ are countably tight. Consequently, $A(\omega_1) = \operatorname*{colim}_{\alpha<\omega_1} A(\alpha)$ and $V(\omega_1) = \operatorname*{colim}_{\alpha<\omega_1} V(\alpha)$ not only as topological algebras, but also as topological spaces.

**Multiples best proximity points for generalised Cyclic (w)- contractions, Room 213**

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Title: Multipled best proximity points for generalized cyclic (w)-contractions.

Abstract: Non-self mappings from A to B do not necessarily have fixed points. However, when A and B are subsets of a distance type space, it is of interest to find elements as close as possible to their image. These elements are called best proximity points. In this paper, we prove the existence of multipled best proximity points of cyclic contractions in metric type spaces. An application is given to illustrate the result. The result generalises, extends and improves earlier related works in literature.

**Balanced and functionally balanced $P$-groups, Room 213**

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In relation to Itzkowitz's problem, we show that a $\mathfrak{c}$-bounded $P$-group is balanced if and only if it is functionally balanced. We prove that for an arbitrary $P$-group, being functionally balanced is equivalent to being strongly functionally balanced. A special focus is given to the uniform free topological group defined over a uniform $P$-space. In particular, we show that this group is (functionally) balanced precisely when its subsets $B_n$, consisting of words of length at most $n$, are all (resp., functionally) balanced.

**The topological entropy and the scale function, Room 213**

Daniele Toller
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If $G$ is a totally disconnected locally compact group, and $\phi : G \to G$ is a continuous group endomorphism of $G$, we show the relation between the scale of $\phi$, and the topological entropy of $\phi$.

**Interpolation sets in compact groups, Room 213**

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Coauthors: Salvador Hernndez and Mara V. Ferrer

In this talk, we will report on some results about the properties and the existence of interpolation sets in the dual set of a compact (non necessary abelian) group. We will especially focus on the notion of central $I_0$ sets.

# Topology + Asymmetric Structures

**On di-injective $T_0$-quasi-metric spaces, Room 205**

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We prove that every q-hyperconvex $T_0$-quasi-metric space $(X, d)$ is di-injective without appealing to Zorn's lemma. We also demonstrate that $Q_X$ as constructed by Kemajou et al. and $Q(X)$ (the space of all Katětov function pairs on $X$) are di-injective. Moreover we prove that di-injective $T_0$-quasi-metric spaces do not contain proper essential extensions. Among other results, we state a number of ways in which the the di-injective envelope of a $T_0$-quasi-metric space can be characterized.

**Decimals and Aspigories, Room 205**

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We discuss approximation of the reals and of other topological algebras using limits of finite neighborhood spaces with very weak algebraic structure. Some properties of the approximated object are determined by corresponding properties of the finite ones (e.g. compactness), while others are induced by properties of the maps (e.g. normality, strong algebraic structure, continuity of operations). This approximation is influenced by categorical ideas, but is carried out in structures more general than categories.

**The Isbell-hull of an asymmetrically normed space, Room 205**

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In this talk, we discuss an explicit method to define the linear structure of the Isbell-hull of an asymmetrically normed space. We use a lot results in [2], and the construction of the Isbell-hull of a $T_0$-quasi-metric space in [1].

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**Enriched Topology and Asymmetry, Room 205**

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Mathematically modeling the question of how to satisfactorily compare, in many-valued ways, both bit-strings and the predicates which they might satisfy—a surprisingly intricate question when the conjunction of predicates need not be commutative—applies notions of enriched categories and enriched functors. Particularly relevant is the notion of a set enriched by a po-groupoid, which turns out to be a many-valued preordered set, along with enriched functors extended as to be "variable-basis". This positions us to model the above question by constructing the notion of topological systems enriched by many-valued preorders, systems whose associated extent spaces motivate the notion of topological spaces enriched by many-valued preorders, spaces which are non-commutative when the underlying lattice-theoretic base is equipped with a non-commutative (semi-)tensor product. Of special interest are crisp and many-valued specialization preorders generated by many-valued topological spaces, orders having these consequences for many-valued spaces: they characterize the well-established $L$-$T_0$ separation axiom, define the $L$-$T_1(1)$ separation axiom—logically equivalent under appropriate lattice-theoretic conditions to the $L$-$T_1$ axiom of T. Kubiak, and define an apparently new $L$-$T_1(2)$ separation axiom. Along with the consequences of such ideas for many-valued spectra, these orders show that asymmetry has a home in many-valued topology comparable in at least some respects to its home in traditional topology.

**Relationships between Hereditary Sobriety, Sobriety, $T_D$, $T_1$, and Locally Hausdorff, Room 205**

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This work augments the standard relationships between sobriety, $T_1$, and Hausdorff by mixing in locally Hausdorff and the compound axioms sober + $T_1$ and sober + $T_D$. We show the latter compound condition characterizes hereditary sobriety, and that locally Hausdorff fits strictly between Hausdorff and sober + $T_1$. Classes of examples are constructed, in part to show the non-reversibility of key implications.

**On quasi-uniform box products, Room 205**

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In this talk, we preset the quasi-uniform box product, a topology that is finer than the Tychonov product topology but coarser than the uniform box product. We then present various notions of completeness of a quasi-uniform space that are preserved by their quasi-uniform box product using Cauchy filter pairs.

**$QH$-singularity of quasi-uniform spaces, Room 205**

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In the book *Uniform Spaces* by Isbell it is wrongfully claimed that the Hausdorff uniformities associated with two distinct uniform structures on a set $X$ define distinct hyperspace topologies. The question for which uniformities this claim is in fact true became known as the Isbell-Smith problem. In this talk we will take a closer look at the Isbell-Smith problem for quasi-uniform spaces. In particular, we will study the properties of $QH$-singular quasi-uniform spaces and describe the $QH$-equivalence class of a transitive quasi-uniformity.

# Topology + Dynamics and Continuum Theory

**Homeomorphic restrictions of unimodal maps, Room 103**
Lori Alvin
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In this talk we provide two symbolic characterizations for a class of unimodal maps whose restriction to the omega-limit set of the turning point is a minimal homeomorphism on a Cantor set. The first characterization is given in terms of the shift space generated by the kneading sequence of the unimodal map, whereas the second characterization relies only on the structure of the kneading sequence.

**Entropy of induced continuum dendrite homeomorphisms, Room 103**
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Coauthors: Alexander Arbieto; Federal University of Rio de Janeiro

Let $f : D \to D$ be a dendrite homeomorphism. Let $C(D)$ denote the hyperspace of all nonempty connected compact subsets of $D$ endowed with the Hausdorff metric. Let $C(f) : C(D) \to C(D)$ be the induced continuum homeomorphism. In this talk we sketch the proof of the following result: If there exists a nonrecurrent branch point then the topological entropy of $C(f)$ is $\infty$.

**Topology and experimental distinguishability, Room 103**
Gabriele Carcassi
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Coauthors: Christine A. Aidala, David J. Baker, Mark J. Greenfield - University of Michigan

In this talk we are going to formalize the relationship between topological spaces and the ability to distinguish objects experimentally, providing understanding and justification as to why topological spaces and continuous functions are pervasive tools in the physical sciences. The aim is to use these ideas as a stepping stone to give a more rigorous physical foundation to dynamical systems and, in particular, Hamiltonian dynamics.

We will first define an experimental observation as a statement that can be verified using an experimental procedure. We will show that observations are not closed under negation and countable conjunction, but are closed under finite conjunction and countable disjunction. We then consider observations that identify elements in a set and show how they induce a Hausdorff and second countable topology on that set, thus identifying an open set as one that can be associated with an experimental observation. For example, the use of the standard topology on Euclidean space corresponds to the ability to measure continuous quantities only with finite precision (i.e. an open interval). We then show that only continuous functions preserve experimental distinguishability and that the collection of these functions can be given a Hausdorff and second countable topology. This shows that the universe of discourse of experimental distinguishability so defined is closed and consistent.

**Entropy Locking, Room 103**

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I show that in certain one-parameter families of piecewise continuous piecewise linear interval maps with two laps, topological entropy stays constant as the parameter varies. The proof is simple and applies to a large set of families.

**Liouville numbers and one-sided ergodic Hilbert transforms, Room 103**

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Coauthors: David Constantine

In joint work with David Constantine, we examine one-sided ergodic Hilbert transforms for irrational circle rotations and some mean-zero functions. Our approach uses continued fraction expansions to specify rotations by Liouville numbers for which the transformation has everywhere convergence or divergence.

**Circular Graph-Like Continua, Room 104**

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A continuum $X$ is 'graph-like' (as defined by Thomassen and Vella) if it contains a zero-dimensional compact subset $V$ such that $X - V$ is a disjoint union of open intervals. The Freudenthal compactification of any locally finite, countable graph is graph-like, and these provide the motivating examples.

We provide characterizations of graph-like continua, connecting them closely to finite graphs. We investigate when graph-like continua have strong connectedness properties, establishing a connection with Eulerian graphs.

**Hausdorff dimension of Kuperberg minimal sets, Room 103**

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The Seifert conjecture was answered negatively in 1994 by Kuperberg who constructed a smooth aperiodic flow on a three-manifold. This construction was later found to contain a minimal set with a complicated topology. The minimal set is embedded as a lamination by surfaces with a Cantor transversal of Lebesgue measure zero. In this talk we will discuss the pseudogroup dynamics on the transversal, the induced symbolic dynamics, and the Hausdorff dimension of the Cantor set.

**The specification property and infinite entropy for certain classes of linear operators, Room 103**

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We study the specification property and infinite topological entropy for two specific types of linear operators: translation operators on weighted Lebesgue function spaces and weighted backward shift operators on sequence $F$-spaces.

It is known from the work of Bartoll, Martinínez-Giménez, Murillo-Arcila (2014), and Peris, that for weighted backward shift operators, the existence of a single non-trivial periodic point is sufficient for specification. We show this also holds for translation operators on weighted Lebesgue function spaces. This implies, in particular, that for these operators, the specification property is equivalent to Devaney chaos. We also show that these forms of chaos imply infinite topological entropy, but that the converse does not hold.

**Shift maps and their variants on inverse limits with set-valued functions, Room 103**

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Coauthors: Kazuhiro Kawamura

We study inverse limits with set-valued functions using a pull-back construction and representing the space as an ordinary inverse limit space, which allows us to prove some known results and their extensions in a unified scheme. We also present a scheme to construct shift dynamics on the limit space and give some examples using the construction.

**Capturing trajectories using non-compact plugs, Room 103**

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A compact plug contains a minimal set, an $\alpha$- and $\omega$-limit set for a usually large set of trajectories. A non-compact plug need not possess a minimal set. We show that non-compact plugs can be used to capture all trajectories in a flow without forming non-empty, closed, invariant subsets. The topology of such flows will be discussed.

**Sequential decreasing strong size properties, Room 103**

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Coauthors: Fernando Orozco, Universidad Autonoma del Estado de Mexico; Felix Capulin, Universidad Autonoma del Estado de Mexico

Let $X$ be a continuum. A topological property $\mathcal{P}$ is said to be a sequential decreasing strong size property provided that if $\mu$ is a strong size map for $C_n(X)$, $\{t_n\}$ is a sequence in the interval $(t, 1)$ such that $\lim t_n = t$ and each fiber $\mu^{-1}(t_n)$ has the property $\mathcal{P}$, then $\mu^{-1}(t)$ has the property $\mathcal{P}$. We show that the following properties are sequential decreasing strong size properties: be a Kelley continuum, indecomposability, local connectedness, continuum chainability and unicoherence.

**Aperiodic graph colorings and dynamics, Room 103**

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A graph coloring is strongly aperiodic if every colored graph in its hull has no automorphisms. The talk will describe a method to define strongly aperiodic colorings on graphs with bounded degree. This also provides an optimal bound for the strongly distinguishing number of a graph. Then some applications to the theory of foliated spaces and to tilings will be discussed.

**A trace formula for foliated flows, Room 103**

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The talk will be about our progress to show a trace formula for foliated flows on foliated spaces, which has been conjectured by V. Guillemin, and later by C. Deninger with more generality. It describes certain Leftchetz distribution of the foliated flow, acting on some version of the leafwise cohomology, in terms of local data at the closed orbits and fixed points.

**Quotients of $n$-fold hyperspaces, Room 103**

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Given a continuum $X$ and an integer $n \geq 2$, let $C_n(X)$ be the $n$-fold hyperspace of $X$ consisting of all nonempty closed subsets of $X$ with at most $n$ components. We consider the quotient space $C_1^n(X) = C_n(X)/C_1(X)$ with the quotient topology. We prove several properties. For example: $C_1^n(X)$ is unicoherent; if $X$ has the property of Kelley, $C_1^n(X)$ is contractible; $\dim(C_n(X)) = \dim(C_1^n(X))$; both $C_1^n([0, 1])$ and $C_1^n(S^1)$ are Cantor manifolds; etc.

**A new class of dendrites having unique second symmetric product, Room 103**

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The *second symmetric product* of a continuum $X$, $F_2(X)$, is the hyperspace consisting of all nonempty subsets of $X$ having at most two points. A continuum $X$ *has unique hyperspace* $F_2(X)$ provided that each continuum $Y$ satisfying that $F_2(X)$ and $F_2(Y)$ are homeomorphic must be homeomorphic to $X$. In this talk, a new class of dendrites having unique $F_2(X)$ will be presented.

**Critical Portraits of Complex Polynomials, Room 103**

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A complex polynomial $P$ of degree $d$ for which all orbits of critical points converge to attracting periodic orbits is said to exhibit hyperbolic dynamics. We consider those for which no critical point is attracted to the attracting fixed point at infinity. For such polynomials, it is well-known that the Julia set $J(P)$ is connected and locally connected. To such a Julia set, there corresponds a *lamination*, a collection of non-crossing chords in the unit disk whose quotient space formed by shrinking the chords to points is dynamically equivalent to $J(P)$.

We propose a high level view of the parameter space of such hyperbolic polynomials through the concept of critical portraits in the context of laminations of the unit disk. For degree $d$, a unit disk with a maximal number of non-crossing chords of critical length (each length $k/d$ for some $k$) that can only meet at endpoints is called a *critical portrait*. In this talk, we will illustrate the connection between $J(P)$ and its corresponding critical portrait, and ultimately a critical portrait corresponding to a family of laminations and corresponding family of Julia sets. We introduce the concept of a *weakly bicolored tree* as a classification scheme for families of laminations

**PSEUDOCONTRACTIBILITY, Room 103**

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Let $X,\ Y$ be topological spaces and let $f,\ g : X \to Y$ be mappings, we say that $f$ is pseudo-homotopic to $g$ if there exist a continuum $C$, points $a,\ b \in C$ and a mapping $H : X \times C \to Y$ such that $H(x, a) = f(x)$ and $H(x, b) = g(x)$ for each $x \in X$. The mapping $H$ is called a pseudo-homotopy between $f$ and $g$. A topological space $X$ is said to be pseudo-contractible if the identity mapping is pseudo-homotopic to a constant mapping in $X$. i.e., if there exist a continuum $C$, points $a,\ b \in C$, $x_0 \in X$ and a mapping $H : X \times C \to X$ satisfying $H(x, a) = x$ and $H(x, b) = x_0$ for each $x \in X$. In this talk we are going to give general facts about pseudo-homotopies and pseudocontractibility. As a consequence of these we can construct more examples of pseudo-contractible continua and non pseudo-contractible continua.

**Eulerian continua, Room 104**

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A finite multi-graph is *Eulerian* if it admits a closed walk that uses every edge exactly once (vertices may be used more than once). It is well-known that a connected graph is Eulerian if and only if every bipartition of its vertex set has an even number of edges between the partition classes.

Generalising this notion, a (Peano-)continuum is said to be *Eulerian* if it is an irreducible image of the unit circle. Bula, Nikiel and Tymchatyn (Can. J. Math., 1994) began to investigate Eulerian Continua, and proposed a conjecture for a characterisation of Eulerian continua. This conjecture has remained unsolved so far.

Inspired by the notion of graph-like continua (a combinatorial analogue of completely regular continua) introduced by Thomassen and Vella (Combinatorica, '08), we have recently established characterisations for Eulerian graph-like continua very much in the spirit of the original graph-theoretic ones (Espinoza, Gartside, Pitz, 2016+). Extending these results, I will explain how these new techniques from combinatorics can be applied to give, in several interesting cases, positive solutions to the Bula-Nikiel-Tymchatyn conjecture.

This is joint with Paul Gartside.

**On Continua with Regular Non-abelian Self Covers, Room 104**

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We look at a planar 2-dimensional continuum $X$ which satisfy the following:

Given any finite group $G$ there is an $|G|$-fold regular self cover $f : X \to X$ with $G$ as its group of deck transformations.

# Topology + Foundations

**On Roitman's principle for box products, Room 214**

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One of the oldest problems in box products is if the countable box product of the convergent sequence is normal. It is known that consistenly (e.g., b=d, d=c) the answer is affirmative. A recent progress is due to Judy Roitman that states a combinatorial principle which also implies the normality and holds in many models.

Although the countable box product of the convergent sequence is normal in some models of b¡d¡c, Roitman asked what happen with her principle in this models. We answer that Roitman's principle is true in some models of b¡d¡c.

**On Cohomological Dimensions of Remainders of Stone-Čech Compactifications, Room 201**

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In the paper the necessary and sufficient conditions are found under which a metrizable space has the Stone-Čech compactification whose remainder has the given cohomological dimensions (cf. [Sm], Problem I, p.332 and Problem II, p.334, and [A-N]).

In the paper [B] an outline of a generalization of Čech homology theory was given by replacing the set of all finite open coverings in the definition of Čech (co)homology group ($\hat{H}^n_f(X, A; G)$) $\hat{H}^f_n(X, A; G)$ (see [E-S],Ch.IX, p.237) by the set of all finite open families of border open coverings [Sm$_1$].

Following Y. Kodama (see the appendix of [N]), we give the following definition:

**Definition 1**. The border small cohomological dimension $d^f_\infty(X; G)$ of normal space $X$ with respect to group $G$ is defined to be the smallest integer $n$ such that, whenever $m \geq n$ and $A$ is closed in $X$, the homomorphism $i^*_{A,\infty} : \hat{H}^m_\infty(X; G) \to \hat{\mathrm{H}}^m_\infty(A; G)$ induced by the inclusion $i : A \to X$ is an epimorphism.

The border small cohomological dimension of $X$ with coefficient group $G$ is a function $d^f_\infty : \mathcal{N} \to \mathrm{N} \cup \{0, +\infty\} : X \to n$, where $d^f_\infty(X; G) = n$ and N is the set of all positive integers.

We have the following results:

**Theorem 2**. Let $X$ be a metrizable space. Then the following equality

$$d^f_\infty(X; G) = d_f(\beta X \setminus X; G)$$

holds, where $d_f(\beta X \setminus X; G)$ is the small cohomological dimension of $\beta X \setminus X$ (see [N], p.199).

**Theorem 3**. Let $A$ be a closed subspace of a normal space $X$. Then

$$d^f_\infty(A; G) \leq d^f_\infty(X; G).$$

**Corollary 4**. For each closed subspace $A$ of a metrizable space $X$,

$$d^f_\infty(A; G) \leq d_f(\beta X \setminus X; G).$$

**Definition 5**. The border large cohomological dimension $D^f_\infty(X; G)$ of normal space $X$ with respect to group $G$ is defined to be the largest integer $n$ such that $\hat{H}^n_\infty(X, A; G) \neq 0$ for some closed set $A$ of $X$.

The border large cohomological dimension of $X$ with coefficient group $G$ is a function $D^f_\infty : \mathcal{N} \to \mathrm{N} \cup \{0, +\infty\} : X \to n$, where $D^f_\infty(X; G) = n$ and N is the set of all positive integers.

**Theorem 6**. For each metrizable space $X$, one has

$$D^f_\infty(X; G) = D_f(\beta X \setminus X; G),$$

where $D_f(\beta X \setminus X; G)$ is the large cohomological dimension of $\beta X \setminus X$ (see [N], p.199).

**Theorem 7**. If $A$ is a closed subset of normal space $X$, then

$$D^f_\infty(A; G) \leq D^f_\infty(X; G).$$

**Corollary 8**. For each closed subspace $A$ of metrizable space $X$, one has

$$D^f_\infty(A; G) \leq D_f(\beta X \setminus X; G).$$

**Theorem 9**. If $X$ is a normal space, then

$$d^f_\infty(X; G) \leq D^f_\infty(X; G).$$

**Corollary 10**. For each metrizable space $X$, one has

$$d_f(\beta X \setminus X; G) \leq D^f_\infty(X; G)$$

and

$$d^f_\infty(X; G) \leq D_f(\beta X \setminus X; G).$$

**Remark 11**.The results of this paper also hold for spaces satisfying the compact axiom of countability [$\text{Sm}_1$]. The locally metrizable spaces, complete in the seance of Čech spaces and locally compact spaces satisfy the compact axiom of countability.

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**Variations on the proximal infinite game, Room 214**

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The proximal infinite game is a two player game played in a uniform space. We will discuss some variants of this game and related topological results.

**On the Chogoshvili Homology Theory of Continuous Maps of Compact Spaces, Room 201**

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In this paper an exact homology functor from the category $\mathbf{Mor_C}$ of continuous maps of compact Hausdorff spaces to the category **LES** of long exact sequences of abelian groups is defined (cf. [2], [3],[5]). This functor is an extension of the Hu homology theory, which is uniquely defined on the category of continuous maps of finite CW complexes and is constructed without the relative homology groups [9]. To define the given homology functor we use the Chogoshvili construction of projective homology theory [7], [8]. For each continuous map $f : X \to Y$ of compact spaces, using the notion of the partition of spaces [7], [8] and approximations of continuous maps [1], [2], [3], V. Baladze defined the inverse system $\mathbf{f} = \{f_\lambda, p_{\lambda\lambda'}, \Lambda\}$, where $\Lambda$ is the directed system of pairs $\lambda = (\alpha, \beta)$ of partitions, where $\alpha$ is refined in $f^{-1}(\beta)$ and $f_\lambda : X_\alpha \to Y_\beta$ is the simplicial map of nerves $X_\alpha$ and $Y_\beta$ of closed coverings defined by partitions $\alpha$ and $\beta$. Using this system he has defined and studied the inverse system of chain complexes $\mathbf{C}_*(\mathbf{f}) = \{C_*(f_\lambda), p^{\#}_{\lambda\lambda'}, \Lambda\}$ and the projective and spectral homology groups:

$$\bar{H}_*(f) \equiv H_*(\varprojlim\{C_*(f_\lambda), p^{\#}_{\lambda\lambda'}, \Lambda\})$$

$$\hat{H}_*(f) \equiv \varprojlim(\{H_*(f_\lambda), p^{\#}_{\lambda\lambda'}, \Lambda\}).$$

A. Beridze has shown that there exists a Milnor short exact sequence (cf. [10], [11], [12]), which connects the defined homology groups:

$$0 \to \varprojlim{}^1 H_{n+1}(f_\lambda) \to \bar{H}_*(f) \to \hat{H}_*(f) \to 0.$$

Using this property, he has shown that the homology groups $\bar{H}_*(f)$ satisfy the universal coefficient formula:

$$0 \to Ext(\hat{H}^{n+1}(f); G) \to \bar{H}_*(f) \to Hom(\hat{H}^n(f); G) \to 0.$$

Consequently, using the methods developed in [4], [6] and [11], we have shown that the constructed functor is unique on the category $Mor_C$.

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**On cardinality bounds involving the weak Lindelöf degree and H-closed spaces, Room 214**

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Coauthors: Angelo Bella, Jack Porter

1. Bella and Carlson give several classes of spaces $X$ for which $|X| \leq 2^{wL(X)\chi(X)}$. This includes locally compact spaces and, more recently, extremally disconnected spaces. Three proofs of the former lead to more general results. One such result is that any regular space $X$ with a $\pi$-base consisting of elements with compact closure satisfies $|X| \leq 2^{wL(X)\chi(X)}$. It is also shown that if $X$ is locally compact and power homogeneous that $|X| \leq 2^{wL(X)t(X)}$, an extension of De la Vega's Theorem.

2. Porter and Carlson give a new cardinality bound for any Hausdorff space that answers a long-standing question of Bella's on H-closed spaces. Using an open ultrafilter assignment, a cardinal invariant $\hat{L}(X)$ is defined with properties a) $\hat{L}(X) \leq L(X)$, b) $\hat{L}(X)$ is countable if $X$ is H-closed, and c) $|X| \leq 2^{\hat{L}(X)\chi(X)}$ for any Hausdorff space X. This gives a common proof of Arhangel'skii's Theorem and the cardinality bound $2^{\chi(X)}$ for H-closed spaces given by Dow and Porter in 1982.

**Sequential order in compact scattered spaces, Room 214**

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A space is sequential if the closure of set can be obtained by iteratively adding limits of converging sequences. The sequential order of a space is a measure of how many iterations are required. A space is scattered if every non-empty set has a relative isolated point. It is not known if it is consistent that there is a countable (or finite) upper bound on the sequential order of a compact sequential space. We consider the properties of compact scattered spaces with infinite sequential order.

**On cardinality of spaces with dense sets of isolated points, Room 214**

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In this talk we will show that if $X$ is a Hausdorff space with a $\pi$-base whose elements have compact closures, then $|X| \leq 2^{wL(X)\psi_c(X)t(X)}$. This generalizes a recent theorem of Bella and Carlson stating that if $X$ is a regular $T_1$-space with a $\pi$-base whose elements have compact closures, then $|X| \leq 2^{wL(X)\psi(X)t(X)}$. It follows directly from our result that if $X$ is a Hausdorff space with a dense set of isolated points, then $|X| \leq 2^{wL(X)\psi_c(X)t(X)}$. Therefore our inequality improves the following previously known cardinal inequalities for a space $X$ with a dense set of isolated points:

(a) [Dow-Porter, 1982] $|X| \leq 2^{wL(X)\chi(X)}$, whenever $X$ is a Hausdorff space;
(b) [Alas, 1993] $|X| \leq 2^{wL_c(X)\psi_c(X)t(X)}$, whenever $X$ is a Hausdorff space; and
(c) [Bella-Carlson, 2016] $|X| \leq 2^{wL(X)\psi(X)t(X)}$, whenever $X$ is a regular $T_1$-space.

**Spaces with no S or L Subspaces, Room 214**

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We show it consistent for spaces $X$ and $Y$ to be both HS and HL even though their product $X \times Y$ contains an S-space. Recall that an S-space is a $T_3$ space that is HS but not HL.

More generally, consider spaces that contain neither an S-space nor an L-space. We say a space is ESLC iff each of its subspaces is either both HS and HL or neither HS nor HL. The "C" in "ESLC" refers to HC; a space is HC iff each of its subspaces has the ccc (countable chain condition) (iff the space has no uncountable discrete subspaces). Classes of ESLC spaces include metric spaces (because every metric space is either second countable or has an uncountable discrete subspace), subspaces of the Sorgenfrey line and (suitably defined) generalized butterfly spaces; for these classes, countable products are still ESLC.

**Disjoint Infinity Borel Functions, Room 214**

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Consider the statement that every uncountable set of reals can be surjected onto R by a Borel function. This is implied by the statement that every uncountable set of reals has a perfect subset. It is also implied by a new statement D which we will discuss: for each real a there is a Borel function $f_a : RtoR$ and for each function $g : RtoR$ there is a countable set G(g) of reals such that the following is true: for each a in R and for each function g : R to R, if $f_a$ is disjoint from g, then a is in G(g). We will show that D follows from ZF $+AD^+$ whereas the negation of D follows from ZFC.

**Uncountable discrete sets and forcing, Room 214**

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Suppose that a space X has no uncountable discrete subspace. We will discuss if forcing can create an uncountable discrete subspace of X.

**A study of closed sets and maps with ideals, Room 201**

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The purpose of this paper is to study a class of closed sets, called generalized pre-closed sets with respect to an ideal (briefly Igp-closed sets), which is an extension of generalized pre-closed sets in general topology. Then, by using these sets, the concepts of Igp- compact spaces along with some classes of maps like continuous and closed maps via ideals have been introduced and analogues of some known results for compact spaces, continuous maps and closed maps in general topology have been obtained.

**Nice spaces and non-normality points, Room 214**

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We define a new class of spaces, which contains all metrizable crowded spaces and Sorgenfray line. Every point of Cech-Stone remainder of a nice space is a non-normality point of the compactification.

**Fuzzy multi-valued Functions between Fuzzy Minimal Spaces, Room 201**

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The biggest difference between fuzzy functions and fuzzy multi-valued functions has to do with the definition of an inverse image. For a fuzzy multi-valued function there are two types of inverses. These two definitions of the inverse then leads to two definitions of continuity. In this paper we introduce upper/ lower M-continuous fuzzy multi-functions as a fuzzy multifunction defined between sets satisfying certain minimal conditions. We obtain some characterizations and some properties of such fuzzy multi-functions. Moreover, we define M-fuzzy compactness and investigate some of its properties. Key words and phrases: Minimal spaces,Fuzzy multifunction, m-compact

**Properties of Weak Domain Representable Spaces, Room 214**

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We will explore some of the basic properties of weak domain representable (wdr) spaces, including hereditary properties and properties of products. In particular, we will construct a Baire space that is not wdr, show that products of wdr spaces are wdr, and demonstrate that the factors of a product that is wdr need not themselves be wdr. We will also show that if $X$ is a wdr space and $Y \subseteq X$ such that $|Y| = |X|$ then $Y$ is wdr. We can declare a subset of a wdr space $X$ to be open or to consist of isolated points without losing the property of being wdr.

**On the Axiomatic Systems of Steenrod Homology Theory of Compact Spaces, Room 201**

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The Steenrod homology theory on the category of compact metric pairs was axiomatically described by J.Milnor. In [6] the uniqueness theorem is proved using the Eilenberg-Steenrod axioms and as well as relative homeomorphism and clusres axioms. J. Milnor constructed the homology theory on the category $Top^2_C$ of compact Hausdorff pairs and proved that on the given category it satisfies nine axioms - the Eilenberg-Steenrod, relative homeomorphis and cluster axioms (see theorem 5 in [6]). Besides, he proved that constructed homology theory satisfies partial continuity property on the subcategory $Top^2_{CM}$ (see theorem 4 in [6]) and the universal coefficient formula on the category $Top^2_C$ (see Lemma 5 in [6]). On the category of compact Hausdorff pairs, different axiomatic systems were proposed by N. Berikashvili [1], [2], H.Inasaridze and L. Mdzinarishvili [4], L. Mdzinarishvili [5] and H.Inasaridze [3], but there was not studied any connection between them. The paper studies this very problem. In particular, in the paper it is proved that any homology theory in Inasaridze sense is the homology theory in the Berikashvili sense, which itself is the homology theory in the Mdzinarishvili sense. On the other hand, it is shown that if a homology theory in the Mdzinarishvili sense is exact functor of the second argument, then it is the homology in the Inasaridze sense.

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**Compactness Via Adherence Dominators, Room 201**

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An adherence dominator on a topological space X is a function $\pi$ from the collection of filterbases on X to the family of closed subsets of X satisfying $A(\Omega) \subseteq \pi(\Omega)$ where $A(\Omega)$ is the adherence $\Omega$. The notations $\pi(\Omega)$ and $A(\Omega)$ are used for the values of the functions $\pi$ and $A$ and $\pi(\Omega) = \cap \Omega \pi F = \cap O \pi V$, where $O$ represents the open members of $\Omega$. The $\pi$ -adherence may be adherence, $\theta$- adherence, $u$-adherence $s$-adherence, $f$-adherence, $\delta$-adherence etc., of a filterbase. Many of the recent theorems by the authors and others on Hausdorff-closed, Urysohn-closed, and regular-closed spaces are subsumed in this paper. It is also shown that a space X is compact if and only if for each upper-semi-continuous relation $\beta$ on $X$ with $\pi$-strongly closed graph, the relation $\mu$ on X defined by $\mu = \pi\beta$ has a maximal value with respect to set inclusion.

**Normal Images of the Product and Countably Paracompact Condensation, Room 214**

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In 1997, Buzjakova proved that for a pseudocompact Tychonoff space $X$ and $\lambda = |\beta X|^+$, $X$ condenses onto a compact space if and only if $X \times (\lambda + 1)$ condenses onto a normal space. This is a condensation form of Tamano's theorem. An interesting problem is to determine how much of Buzjakova's result will hold if "pseudocompact" is removed from the hypothesis.

In this talk, I am going to show for a Tychonoff space $X$, there is a cardinal $\lambda$ such that if $X \times (\lambda + 1)$ condenses onto a normal space, then $X$ condenses onto a countably paracompact space.

**Monotone interior-preserving open operators, Room 214**

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Ted Porter and the speaker proved (using different approaches) that the Sorgenfrey line does not have a monotone closure-preserving operator. In contrast, we prove that it has a monotone interior-preserving open operator. We do not know if the space $\omega_1$ of all countable ordinals with the order topology has a monotone interior-preserving open operator. We state an order-theoretic translation of this question, and discuss other monotove versions of paracopmactness-like properties.

**REVELATION OF NANO TOPOLOGY IN CECH ROUGH CLOSURE SPACES, Room 201**

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The concept of Cech closure space was initiated and developed by E. Cech in 1966 [1,2]. Henceforth many more research scholars [6] set their minds in this theory and developed it to a new height. Pawlak.Z [5] derived and gave shape to Rough set theory in terms of approximation using equivalence relation known as indiscernibility relation. Further Lellis Thivagar [3] enhanced rough set theory into a topology, called Nano Topology, which has at most

five elements in it and he [4] also extended this into multi granular nano topology. The purpose of this paper is to derive Nano topology in terms of Cech rough closure operators. In addition to this, we also establish the continuous functions on Cech rough closure space and its properties. From these, we evolve a Cech nano topological space that satisfies the topological axioms on infinite universe.

2010 MSC: 54A05, 03B50, 03B52.

Keywords: Rough sets, Cech rough closure operators, Cech rough continuity, Cech nano topological spaces.

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**Relationships between topological properties of $X$ and algebraic properties of intermediate rings $A(X)$, Room 214**

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A topological property is a property invariant under homeomorphism, and an algebraic property of a ring is a property invariant under ring isomorphism. Let $C(X)$ be the ring of real-valued continuous functions on a Tychonoff space $X$, let $C^*(X) \subseteq C(X)$ be the subring of those functions that are bounded, and call a ring $A(X)$ an *intermediate ring* if $C^*(X) \subseteq A(X) \subseteq C(X)$. For a class $Q$ of intermediate rings, an algebraic property $P$ *describes* a topological property $T$ among $Q$ if for all $A(X), B(Y) \in Q$ if $A(X)$ and $B(Y)$ both satisfy $P$, then $X$ satisfies $T$ if and only if $Y$ satisfies $T$. An example of a topological property being described by an algebraic property among a class of intermediate rings is that of a $P$*-space*, a Tychonoff space in which every zero-set is open. We see that the property that *every prime ideal of the ring is maximal* describes $P$-spaces among rings $C(X)$, however for the same algebraic property does not describe $P$-spaces among all intermediate rings. Another example of a topological property is that of an $F$*-space*, a Tychonoff space in which disjoint co-zero sets are completely separated. We see that the property that *the set of prime ideals contained in a maximal ideal form a chain* describes $F$-spaces among all intermediate rings. We investigate what other algebraic properties describe topological properties as well as other types of relationships between algebraic properties and topological properties, and we prove some theorems about how certain topological properties relate to algebraic properties of intermediate rings.

**Cohen reals and the sequential order of groups, Room 214**

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We show that adding uncountably many Cohen reals to a model of diamond results in a model with no countable sequential group with an intermediate sequential order. The same model has an uncountable group of sequential order 2. We also discuss related questions.

**The Scheepers property and products of Menger spaces, Room 214**

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A topological space $X$ is Menger if for every sequence of open covers $\mathcal{O}_1, \mathcal{O}_2, \ldots$ of the space $X$, there are finite subfamilies $\mathcal{F}_1 \subseteq \mathcal{O}_1$, $\mathcal{F}_2 \subseteq \mathcal{O}_2$, ... such that their union is a cover of $X$. If, in addition, every finite subset of $X$ is contained in the set $\bigcup \mathcal{F}_n$ for some natural number $n$, then the space $X$ is Scheepers. The above properties generalize $\sigma$-compactness, and Scheepers' property is formally stronger than Mengers property. It is consistent with ZFC that these properties are equal.

One of the open problems in the field of selection principles is to find the minimal hypothesis that the above properties can be separated in the class of sets of reals. Using purely combinatorial approach, we provide examples under some set theoretic hypotheses. We apply obtained results to products of Menger spaces and products of function spaces with the pointwise convergence topology.

**Some applications of the point-open subbase game, Room 214**

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Given a subbase $S$ of a space $X$, the game $PO(S, X)$ is defined for two players $P$ and $O$ who respectively pick, at the n-th move, a point $x_n \in X$ and a set $U_n \in S$ such that $x_n \in U_n$ . The game stops after the moves $\{x_n, U_n : n \in \omega\}$ have been made and the player $P$ wins if the union of the $U_n$'s equals X; otherwise $O$ is the winner. Since $PO(S, X)$ is an evident modification of the well-known point-open game $PO(X)$, the primary line of research is to describe the relationship between $PO(X)$ and $PO(S, X)$ for a given subbase S. It turns out that, for any subbase $S$, the player $P$ has a winning strategy in $PO(S, X)$ if and only if he has one in $PO(X)$. However, these games are not equivalent for the player $O$: there exists even a discrete space $X$ with a subbase $S$ such that neither $P$ nor $O$ has a winning strategy in the game $PO(S, X)$. Given a compact space $X$, we show that the games $PO(S, X)$ and $PO(X)$ are equivalent for any subbase $S$ of the space $X$.

**Fiber Strong Shape Theory for Topological Spaces, Room 201**

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The purpose of this paper is the construction and investigation of fiber strong shape theory for compact metrizable spaces over a fixed base space $B_0$, using the fiber versions of cotelescop, fibrant space and SSDR-map. In the paper obtained results containing the characterizations of fiber strong shape equivalences, based on the notion of double mapping cylinder over a fixed space $B_0$. Besides, in the paper we construct and develop a fiber strong shape theory for arbitrary spaces over fixed metrizable space $B_0$. Our approach is based on the method of Mardešić-Lisica and instead of resolutions, introduced by Mardešić, their fiber preserving analogues [1] are used.

The fiber strong shape theory yields the classification of spaces over $B_0$ which is coarser than the classification of spaces over $B_0$ induced by fiber homotopy theory, but is finer than the classification of spaces over $B_0$ given by usual fiber shape theory.

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**On the paracompactness of linearly stratifiable spaces, Room 214**

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Linearly stratifiable spaces, more specifically spaces stratifiable over $\omega_\mu$, where $\omega_\mu$ is an infinite cardinal, are generalization to arbitrary cardinals of the well known concepts of stratifiable spaces. We consider two properties possessed by every space stratifiable over $\omega_\mu$. A space is called a *weak $P(\omega_\mu)$-space* provided every subset of cardinality less than $\omega_\mu$ is closed. A space is called an *$\omega_\mu$-perfect space* provided every closed set is the intersection of less than $\omega_\mu$ open sets. If we consider the countable case in these definitions, we get the standard concepts of stratifiable space, weak $P$-space and perfect space. Our somewhat unexpected main result states: If X is monotonically normal, and both a weak P($\omega_\mu$)-space and an $\omega_\mu$-perfect space, then X is paracompact. The assumption of monotonic normality allows us to call on the Balogh-Rudin Theorem: A monotonically normal space is paracompact if and only if it has no closed subsets homeomorphic to a stationary subset of a regular uncountable cardinal with its order topology. In order to invoke the Balogh-Rudin theorem, we prove some facts about the topology of stationary subsets of regular uncountable cardinals (with the subspace topology inherited from the usual order topology on the cardinal). As an easy corollary we get an entirely different proof of the known theorem that spaces stratifiable over $\omega_\mu$ are paracompact.

**Some New Completeness Properties in Topological Spaces, Room 201**

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One of the most widely known completeness property is the completeness of metric spaces and the other one being of a topological space in the sense of Cech. It is well known that a metrizable space $X$ is completely metrizable if and only if $X$ is Cech-complete. One of the generalisations of completeness of metric spaces is subcompactness. It has been established that, for metrizable spaces, subcompactness is equivalent to Cech-completeness. Also the concept of domain representability can be considered as a completeness property. In [1], Bennett and Lutzer proved that Cech-complete spaces are domain representable. They also proved, in [2], that subcompact regular spaces are domain representable. Then Fleissner and Yengulalp, in [3], gave a simplified characterization of domain representability. In this work, we introduce the completeness of a quasi-pair-base and study the topological spaces having such a base. Our results include the fact that Cech-complete spaces and subcompact spaces have complete quasi-pair-basis, and we prove that if a topological space $X$ has a complete quasi-pair-base then $X$ is domain representable.

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# Topology + Geometry

**On direct product stability of asymptotic property C, Room 109**

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Asymptotic property C is a dimension-like large-scale invariant of metric spaces that is of interest when applied to spaces with infinite asymptotic dimension. It was first described by Dranishnikov, who based it on Haver's topological property C. Topological property C fails to be preserved by products in very striking ways and so a natural question that remained open for some 10+ years is whether asymptotic property C is preserved by products. Using a technique inspired by Rohm we show that asymptotic property C is preserved by direct products of metric spaces.

**Virtual Seifert surfaces and slice obstructions for knots in thickened surfaces, Room 109**

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For $i = 0, 1$, let $K_i$ be an oriented knot in $\Sigma_i \times \mathbb{I}$, where $\Sigma_i$ is a compact oriented surface and $\mathbb{I} = [0, 1]$. Then $K_0$ and $K_1$ are said to be concordant if there is a compact oriented 3-manifold $M$ and an embedding $\Sigma_1 \sqcup -\Sigma_0 \hookrightarrow \partial M$ such that $K_1 \sqcup -K_0$ bounds an annulus in $M \times \mathbb{I}$. A knot $K$ in $\Sigma \times \mathbb{I}$ is said to be slice if it is concordant to the unknot in $\mathbb{S}^2 \times \mathbb{I}$. This geometric definition, due to Turaev [Tu], is equivalent to concordance of virtual knots as defined by Dye-Kaestner-Kauffman [DKK] and Carter-Kamada-Saito [CKS].

Homologically trivial knots in $\Sigma \times \mathbb{I}$ correspond to the collection of virtual knots called almost classical knots (AC knots). Here we introduce the notion of virtual Seifert surfaces. Virtual Seifert surfaces may be thought of as a generalization of Gauss diagrams of virtual knots to spanning surfaces of a knot. This device is then employed to extend the Tristram-Levine signature function to AC knots. Using the AC signature functions and Tuarev's graded genus invariant, we determine the slice status of all 76 almost classical knots having at most six crossings. The slice obstructions for AC knots are then extended to all virtual knots via the parity projection map. This map, which is computable from a Gauss diagram, sends a concordance class of virtual knots to a concordance class of AC knots.

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**Curve shortening to find geodesics in CAT(0) spaces of trees, Room 109**

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Billera, Holmes, and Vogtmann introduced a CAT(0) complex whose points are phylogenetic trees on a specified set of taxa. Finding geodesics between points of these spaces gives not only a useful distance between trees, but also a way to interpolate between trees. Algorithms for finding geodesics in these spaces are often difficult because of the many cells present. We describe an approach for finding geodesics efficiently based upon iterative curve shortening.

**Hyperbolization on infinite type 3-manifolds, Room 109**

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In this talk we will provide an answer to the following question posed by Agol:

Question (Agol). Is there a 3-dimensional manifold M with no divisible subgroups in its fundamental group that is locally hyperbolic but not hyperbolic?

To do so we will construct a 3-manifold M that is locally hyperbolic and without divisible subgroups but such that it does not admit a hyperbolic structure. We will then state a characterisation of hyperbolizable 3-manifolds in the following class: 3- manifolds that admit an exhaustion by hyperbolizable 3-manifolds with incompressible boundary such that all boundary components have uniformly bounded genera.

**Superinjective Simplicial Maps of the Two-sided Curve Complexeson Nonorientable Surfaces, Room 109**

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I will talk abouta joint work with Luis Paris. We prove that on a compact, connected, nonorientable surface of genus at least 5,any superinjective simplicial map from the two-sided curve complex to itself is induced by a homeomorphismthat is unique up to isotopy. Iwill also talk aboutan application in the mapping class groups.

**Totally geodesic surfaces in arithmetic hyperbolic 3-manifolds, Room 109**

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In this talk we will discuss some recent work on the problem of determining the extent to which the geometry of an arithmetic hyperbolic 3-manifold M is determined by the geometric genus spectrum of M (i.e., the set of isometry classes of finite area, properly immersed, totally geodesic surfaces of M, considered up to free homotopy). In particular, we will give bounds on the totally geodesic 2-systole, construct infinitely many incommensurable manifolds with the same initial geometric genus spectrum and analyze the growth of the genera of minimal surfaces across commensurability classes. These results have applications to the study of how Heegard genus grows across commensurability classes.

**Subgroups of relatively hyperbolic groups of relative dimension 2, Room 109**

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A remarkable result of Gersten states that the class of hyperbolic groups of cohomological dimension 2 is closed under taking finitely presented subgroups. We prove the analogous result for toral relatively hyperbolic groups of dimension 2 with respect to the family of parabolic subgroups. The proof relies on an algebraic approach to relative homological Dehn functions, and a new characterization of relative hyperbolicity. In the talk, I will describe the result and some applications, and briefly describe some of the tools used in the proof.

**Title: CAT(0) groups, rigidity, and the morse boundary, Room 109**

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In geometric group theory a finitely presented group is often identified with its Cayley graph. Unfortunately, the Cayley graph depends on the generating set of the group, and is only well defined up to quasi-isometry. Because quasi-isometries are such a weak geometric equivalence a natural question to ask is, if two groups are quasi-isometric how similar are they as groups? For some classes of groups the answer is quite surprising! For example, a group which is quasi-isometric to the fundamental group of a surface group is (virtually) isomorphic to a surface group! A class of groups which exhibits this property is called quasi-isometrically rigid.

Many classes of groups are quasi-isometrically rigid, free abelian groups, finite volume discrete subgroups of a non-compact Lie group, surface groups, etc. Often, negative or non-positive curvature plays an important role in proving rigidity theorems.

CAT(0) groups are a natural generalization of non-positively curved manifold groups. The morse boundary is a quasi-isometry invariant for CAT(0) groups that serves a similar role that the boundary of hyperbolic n-space serves for hyperbolic manifold groups. I will introduce all of the objects in question and talk about some results for the morse boundary that make it a promising tool to study the quasi-isometric rigidity of some classes of CAT(0) groups.

**Compactifications of unstable Nöbeling spaces, Room 109**

Andrzej Nagorko
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This work revolves around two major open conjectures of dimension theory.

Conjecture 1. Every $k$-dimensional subset of the $n$-dimensional Euclidean space $R^n$ has a $k$-dimensional compactification that embeds into $R^n$.

Conjecture 2. A $k$-dimensional Menger cube $M_k^n \subset R^n$ contains a topological copy of every $k$-dimensional subset of $R^n$.

A deep theorem of Stanko from 1971 implies that these conjectures are equivalent. Hurewicz and Wallman wrote in 1941 that Conjecture 1 is the most important open conjecture left in dimension theory. It is still open.

Nobeling space $N_k^n$ is a subset of $R^n$ consisting of points with at most $k$ rational coordinates. It is conjectured to be a universal space for $k$-dimensional subsets of $R^n$. Hence a natural question, asked by Engelking in 1978.

Question. Does $N_k^n$ embed into $M_k^n$?

We answer this question affirmatively. We prove that $N_k^n$ has a $k$-dimensional compactification that embeds into $R^n$. By Stanko's theorem, $M_k^n$ is universal for $k$-dimensional compact subsets of $R^n$. Hence $N_k^n$ embeds into $M_k^n$.

**Decomposing CAT(0) Cube Complexes, Room 109**

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It is known that if a CAT(0) cube complex decomposes as a product, then any group of automorphisms must virtually act as a the product of automorphisms of the factors. My talk will discuss how much we can say about a CAT(0) cube complex which admits a nice enough action by a product of groups.

**The outer automorphism group of a right-angled Coxeter group is either large or virtually abelian, Room 109**

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In the study of automorphisms of graph products of cyclic groups (including RAAGs and RACGs), a separating intersection of links (SIL) has been shown to hold a lot of power. The reason for this is that a SIL is exactly the necessary condition on the underlying graph that determines when two partial conjugations do not commute. We introduce two variations on a SIL that give a combinatorial condition on a right-angled Coxeter group that determine the dichotomy given in the title: the outer automorphism group of a RACG has a finite index subgroup that is either abelian or maps onto F2. This is joint work with Tim Susse.

**Manifold Models for Hyperplane Complements, Room 109**

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A complex hyperplane arrangement is a collection of affine hyperplanes in $C^n$. The space obtained by removing these hyperplanes is called the hyperplane complement. The hyperplane complement is a noncompact manifold of dimension 2n. We are interested in when this complement is homotopy equivalent to a manifold of smaller dimension. Our main result is that this almost always occurs when the complement is aspherical.

**Uncountably many quasi-isometry classes of groups of type FP, Room 109**

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An interplay between algebra and topology goes in many ways. Given a space $X$, we can study its homology and homotopy groups. In the other direction, given a group $G$, we can form its Eilenberg–Maclane space $K(G, 1)$. It is natural to wish that it is 'small' in some sense. If $K(G, 1)$ space has $n$–skeleton with finitely many cells, then $G$ is said to have type $F_n$. Such groups act naturally on the cellular chain complex of the universal cover for $K(G, 1)$, which has finitely generated free modules in all dimensions up to $n$. On the other hand, if the group ring $\mathbb{Z}G$ has a projective resolution $(P_i)$ of length $n$ where each module $P_i$ is finitely generated, then $G$ is said to have type $FP_n$. There have been many intriguing questions on whether classes $F_n$ and $FP_n$ are different, and some of them are still open. Bestvina and Brady gave first examples of groups of type $FP_2$ which are not finitely presentable (i.e. not of type $F_2$). In his recent paper, Ian Leary has produced uncountably many of such groups. Using Bowditch's concept of taut loops in Cayley graphs, we show that Ian Leary's groups actually form uncountably many classes up to quasi-isometry.

**simplicial volume of nonpositively curved manifolds, Room 109**

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In this talk, I will discuss the notion of simplicial volume introduced by Gromov and Thurston. For nonpositively curved manifolds, Gromov conjectured that negative Ricci curvature implies postivitity of simplicial volume. I will talk about some recent work joint with Chris Connell. We show that, under a stronger curvature condition, the simplicial volume is always positive, this answers a special case of Gromov's problem.

**Extension theorems for large scale spaces via neighbourhood operators, Room 109**

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Coarse geometry is the study of the large scale behaviour of spaces. The motivation for studying such behaviour comes mainly from index theory and geometric group theory. In this talk we introduce the notion of (hybrid) large scale normality for large scale spaces and prove analogues of Urysohns Lemma and the Tietze Extension Theorem for spaces with this property, where continuous maps are replaced by (continuous and) slowly oscillating maps. To do so, we first prove a general form of each of these results in the context of a set equipped with a neighbourhood operator satisfying certain axioms, from which we obtain both the classical topological results and the (hybrid) large scale results as corollaries. We prove that all metric spaces are large scale normal, and give some examples of spaces which are not hybrid large scale normal. Finally, we look at some properties of Higson coronas of hybrid large scale normal spaces.

**Cyclic branched covers of the sphere, Room 109**

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Birman and Hilden ask: given finite branched cover X over the 2-sphere, does every homeomorphism of the sphere lift to a homeomorphism of X? For covers of degree 2, the answer is yes, but the answer is sometimes yes and sometimes no for higher degree covers. In joint work with Ghaswala, we completely answer the question for cyclic branched covers. When the answer is yes, there is an embedding of the mapping class group of the sphere into a finite quotient of the mapping class group of X. In a family where the answer is no, we find a presentation for the group of isotopy classes of homeomorphisms of the sphere that do lift, which is a finite index subgroup of the mapping class group of the sphere.

**Rigidity of quasiisometries of nilpotent Lie groups and negatively curved solvable Lie groups, Room 109**

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I will give a survey of recent progresses on the rigidity of quasiisometries of nilpotent Lie groups and negatively curved solvable Lie groups.