# Schedule

| Time | Monday CO1 | CO2 |
|---|---|---|
| 8:15 – 8:45 | Registration | |
| 8:45 – 9:00 | Welcome | |
| 9:00 – 10:00 | Professor Gunnar Carlsson<br>*Lecture 1* | |
| ☕ | *Coffee break, ROOM CO122* | |
| 10:30 – 11:00 | Gabrovšek Boštjan<br>*Skein modules* | Wierstra Felix<br>*Applications of Koszul duality in algebraic topology* |
| 11:15 – 11:45 | Anghel Cristina Ana-Maria<br>*Renormalized quantum dimension and multivariable invariants for links* | Börjeson Kaj<br>*Free loop spaces and Koszul duality* |
| 12:00 – 12:30 | Damiani Celeste<br>*On the Alexander polynomial of a tangle* | Maunder James<br>*The homotopy theory of differential graded coalgebras and marked curved Lie algebras* |
| Lunch | | |
| 14:00 – 15:00 | Professor Gunnar Carlsson<br>*Lecture 2* | |
| ☕ | *Coffee break, ROOM: CO122* | |
| 15:30 – 16:00 | Kudryashov Alexei<br>*Topology and Combinatorics of Quasitoric Manifolds* | Bello Hugo<br>*Splittings and products of topological abelian groups* |
| 16:15 – 16:45 | D'Mello Shane<br>*Chord Diagrams and Generic Real Rational Planar Curves of Degree 4* | Stephan Marc<br>*Finite group actions on two-dimensional complexes* |
| 17:00 – 17:30 | Santander Egas Daniela<br>*Arc operads and the Moduli space of surfaces* | Garaialde Oihana<br>*p-local finite groups and partial groups* |
| 17:45 – 18:15 | Ward Benjamin<br>*Moduli space actions and cyclic operads* | Egger Philip<br>*Spectral sequences and nilpotence* |

| Time | Tuesday CO1 | CO2 |
|---|---|---|
| 9:00 – 10:00 | Professor Gunnar Carlsson<br>*Lecture 3* | |
| ☕ | *Coffee break, ROOM: CO122* | |
| 10:30 – 11:00 | Grigoriev Ilya<br>*Characteristic classes of manifold bundles* | Malkiewich Cary<br>*An introduction to cyclic sets and cyclotomic spectra* |
| 11:15 – 11:45 | West Michael<br>*Homotopy Decompositions of Gauge Groups over Klein Surfaces* | Angelini-Knoll Gabriel<br>*THH of the connective cover of the $K(1)$-local sphere* |
| 12:00 – 12:30 | Wassermann Thomas<br>*Spin TQFTs and Anyons* | Ungheretti Massimiliano<br>*A dihedral version of the Jones isomorphism* |
| Lunch | | |
| 14:00 – 15:00 | Professor Emily Riehl<br>*Lecture 1* | |
| ☕ | *Coffee break, ROOM: CO122* | |
| 15:30 – 16:00 | Penney Mark<br>*Homotopy Fixed Points and the Classification of 2D Topological Field Theories* | Beardsley Jonathan<br>*Thom Spectra and Coalgebraic Structure* |
| 16:15 – 16:45 | Catanzaro Michael<br>*A generalization of the Boltzmann distribution and Hodge theory* | Konter Johan<br>*Obstruction theory for logarithmic ring spectra* |
| 17:00 – 17:30 | Zeidler Rudolf<br>*Positive scalar curvature and secondary index theory* | Heard Drew<br>*The $E_2$-term of the $K(n)$-local $E_n$ Adams spectral sequence* |
| 17:45 – 18:15 | Rust Dan<br>*The Strange Topology of Aperiodic Tilings and Their Cohomology* | Gallauer Martin<br>*Traces in monoidal derivators* |
| 18:30 – | Conference dinner | |

| Time | Wednesday CO1 | CO2 |
|---|---|---|
| 9:00 – 10:00 | Professor Gunnar Carlsson *Lecture 4* | |
| ☕ | *Coffee break, ROOM: CO122* | |
| 10:30 – 11:00 | Scolamiero Martina *Multidimensional Persistence and Noise* | Zielenkiewicz Magdalena *Goresky-Kottwitz-MacPherson graphs and their applications in equivariant cohomology* |
| 11:15 – 11:45 | Filakovsky Marek *Deciding whether two equivariant maps are homotopic* | Burfitt Matthew *Free loop cohomology of complete flag manifolds* |
| 12:00 – 12:30 | Balchin Scott *Developments in Topological Data Analysis* | Low Zhen Lin *Cocycles in categories of fibrant objects* |
| Lunch | | |
| 14:00 – 15:00 | Professor Emily Riehl *Lecture 2* | |
| ☕ | *Coffee break, ROOM: CO122* | |
| 15:30 – 16:00 | Nadareishvili George *Subcategory lattice of noncommutative spaces* | Barma Abdoul Kader Yacouba *Rational homotopy type of the space of immersions* |
| 16:15 – 16:45 | Adams Henry (Room INF3) *Exercises for Gunnar Carlsson's lecture* | Yeakel Sarah *New chain rule for the homotopy calculus of functors* |
| 17:00 – 17:30 | Adams Henry (Room INF3) *Exercises for Gunnar Carlsson's lecture* | Tebbe Amelia *Computing the Goodwillie-Taylor Tower for Atomic Discrete Modules* |
| 17:45 – 18:15 | Adams Henry (Room INF3) *Exercises for Gunnar Carlsson's lecture* | Prasma Matan *The Grothendieck Construction for Model Categories* |
| 18:30 – | | |

| Time | Thursday CO1 | CO2 |
|---|---|---|
| 9:00 – 10:00 | Professor Emily Riehl<br>*Lecture 3* | |
| ☕ | *Coffee break, ROOM: CO122* | |
| 10:30 – 11:00 | Otter Nina<br>*The phylogenetic operad* | Weighill Thomas<br>*A characterization of R1-spaces via a Mal'tsev condition* |
| 11:15 – 11:45 | Kalisnik Verovsek Sara<br>*Parametrized homology and Parametrized Alexander Duality Theorem* | Dungan Ivan<br>*'n-Butterflies: Modeling Morphisms between Strict n-Groups* |
| 12:00 – 12:30 | Belchi Francisco<br>*A-infinity structures and Persistent Homology* | Schaeppi Daniel<br>*Tannaka duality and Adams Hopf algebroids* |
| Excursion | | |

| Time | Friday CO1 | CO2 |
|---|---|---|
| 9:00 – 10:00 | Professor Emily Riehl<br>*Lecture 4* | |
| ☕ | *Coffee break, ROOM: CO122* | |
| 10:30 – 11:00 | Reeh Sune<br>*Saturated fusion systems as stable retracts of groups* | Le Grignou Brice<br>*From homotopy operads to infinity-operads* |
| 11:15 – 11:45 | Molinier Rémi<br>*Classifying spaces of saturated fusion systems and their cohomology* | White David<br>*The Baez-Dolan Stabilization Hypothesis and Left Proper Model Structures on Operads* |
| 12:00 – 12:30 | Araujo Manuel<br>*Fusion categories and 3-dimensional topological field theories* | Balzin Eduard<br>*Derived sections and categorical resolutions in homotopical context* |

# Lectures

## Gunnar Carlsson (Stanford University)

**Methods of applied topology**

There is a lot of discussion around the topic of "Big Data", which means the study of large and complex data sets. From a mathematical point of view, these data sets typically have the structure of finite metric spaces, sometimes in numerous ways. The problem of analyzing these data sets is a very important one in the sciences, engineering, and commerce. Any kind of organizing principle for them would be a major contribution to the solution of these problems. It turns out that topology is a very useful such principle, both via versions of complex constructions as well as homology. This course will discuss these ideas, with numerous examples, and will as provide instruction on the use of persistent homology software.

## Emily Riehl (Harvard University)

**Infinity category theory from scratch**

We use the terms $\infty$-categories and $\infty$-functors to mean the objects and morphisms in an $\infty$-cosmos: a simplicially enriched category satisfying a few axioms, reminiscent of an enriched category of "fibrant objects." Quasi-categories, Segal categories, complete Segal spaces, iterated complete Segal spaces, and fibered versions of each of these are all all $\infty$-categories in this sense. In joint work with Dominic Verity, we show that the basic category theory of $\infty$-categories and $\infty$-functors can be developed only in reference to the axioms of an $\infty$-cosmos; indeed, most of the work is internal to a strict 2-category of $\infty$-categories, $\infty$-functors, and natural transformations. In the $\infty$-cosmos of quasi-categories, we recapture precisely the same category theory developed by Joyal and Lurie, although in most cases our definitions, which are 2-categorical rather than combinatorial in nature, present a new incarnation of the classical concept.

In the first lecture, we define an $\infty$-cosmos and introduce its homotopy 2-category, the strict 2-category mentioned above. We illustrate the use of formal category theory to develop the basic theory of equivalences of and adjunctions between $\infty$-categories. In the second lecture, we study limits and colimits of diagrams taking values in an $\infty$-category and relate these concepts to adjunctions between $\infty$-categories. In the third lecture, we define comma $\infty$-categories, which satisfy a particular weak 2-dimensional universal property in the homotopy 2-category. We illustrate the use of comma $\infty$-categories to encode the universal properties of (co)limits and adjointness. Because comma $\infty$-categories are preserved by all functors of $\infty$-cosmoi and reflected by certain weak equivalences of $\infty$-cosmoi, these characterizations form the foundations for "model independence'" results. In the fourth lecture, we introduce (co)cartesian fibrations, a certain class of $\infty$-functors, and their groupoidal variants. We then describe the calculus of modules, between $\infty$-categories — comma $\infty$-categories being the prototypical example — and use this framework to state and prove the Yoneda lemma and develop the theory of pointwise Kan extensions along $\infty$-functors.

## Monday morning, room CO1

### Gabrovšek Boštjan

**Skein modules**

Take a commutative ring with identity $R$ and a 3-manifold $M$ and consider the free $R$-module over the isotopy classes of links in $M$ modulo the submodule generated by properly chosen skein relations between these classes. What we are left with is an algebraic object associated to $M$ which is called the skein module of $M$. Skein modules capture essential information about the geometry of the 3-manifold as they reflect the interaction between embedded 1-dimensional and 2-dimensional submanifolds. For example, the existence of an embedded non- separating closed surface in $M$ produces torsion in the module. On the other hand, by varying the skein relation, we can use skein modules to derive generalizations of classical knot polynomials for knots in arbitrary 3- manifolds. We will give an exposition of the results for the Kauffman bracket skein module and present recent results of the calculation of the HOMFLY-PT skein module of lens spaces.

### Anghel Cristina Ana-Maria

**Renormalized quantum dimension and multivariable invariants for links**

The aim of this talk is to present a class of multivariable link invariants constructed from a super Lie algebra of type I and their relations with Kashaev's invariants and the Volume Conjecture. In the first part of the talk, after a short introduction concerning the classical Reshetikhin-Turaev construction [5], we will describe the multivariable link invariants introduced by Geer and Patureau in [1]. The main idea is to use the "renormalized quantum dimension" of a module instead of the usual quantum dimension to adapt the classical Reshetikhin-Turaev method in the Lie super-algebras of type I situation. The second part will be devoted to the connection be- tween the multivariable link invariants and HOMFLY-PT and Kashaev's invariants. We will explain how the intersection between the multivariable invariants and the colored HOMFLY-PT polynomials contains the Kashaev's invariants [2].

[1] N. Geer, B. Patureau-Mirand, Multivariable link invariants arising from Lie super algebras of type I, J. Knot Theory Ramifications 19, Issue 1 (2010) 93-115

[2] N. Geer, B. Patureau-Mirand, On the Colored HOMFLY-PT, Multivariable and Kashaev Link Invariants, Commun. Contemp. Math. 10 (2008), no. 1 supp, 993-1011

[3] R.M. Kashaev, A link invariant from quantum dilogarithm, Modern Phys. Lett. A 10 (1995), no. 19, 14091418.

[4] H. Murakami, J. Murakami, The colored Jones polynomials and the simplicial volume of a knot, Acta Math. 186 (2001), no. 1, 85104

[5] N. Reshetikhin, V. Turaev, Invariants of 3-manifolds via link polynomials and quantum groups, Invent. Math. 103 (1991), 547-598

### Damiani Celeste

**On the Alexander polynomial of a tangle**

Ribbon 2-knotted objects are locally flat 2-dimensional submanifolds of $\mathbb{R}^4$ that bound immersed 3-manifolds with only ribbon singularities. They appear as topological realizations of welded knotted objects, where welded knot theory is a quotient of virtual knot theory. We construct a functorial extension of the Alexander polynomial to ribbon tangles. At a combinatorial level this gives rise to a generalization of the Alexander polynomial of links to welded tangles.

# Monday morning, room CO2

## Wierstra Felix

**Applications of Koszul duality in algebraic topology**

In this talk I will give an introduction to the theory of Koszul duality and sketch some of its applications to topology. Koszul duality is a special kind of duality for certain good algebras that makes these algebras easier to understand. It is for example very easy to find minimal free resolutions for Koszul algebras and to compute there Ext and Tor. In topology Koszul duality has many applications, for example for good spaces it can be used to compute the rational homology of the n-fold loop space. Another application is in rational homotopy theory where Koszul duality gives a duality between Sullivan's commutative differential graded model and Quillen's Lie model for a space.

## Börjeson Kaj

**Free loop spaces and Koszul duality**

The notions of formality and coformality of spaces are closely linked to the algebraic notion of Koszul duality. I will explain what these concepts are and what the connection looks like. This machinery enables us to compute homologies of free loop spaces that may otherwise be quite tricky. I will describe how this applies to the free loop space of any $(n-1)$-connected manifold of dimension at most $3n-2$.

## Maunder James

**The homotopy theory of differential graded coalgebras and marked curved Lie algebras**

Differential graded coalgebras arise for example as representing objects for formal deformation functors and they also play a prominent role in rational homotopy theory. As such, cocommutative differential graded coalgebras (subject to some conditions such as requiring them to be conilpotent) have been placed in the framework of a closed model category. A particularly pleasant property possessed by some of these constructions is the so-called Koszul duality: the closed model category is Quillen equivalent to a certain closed model category of differential graded Lie algebras. Within this talk, some recent work regarding the generalization of this construction to the category of cocommutative differential graded coalgebras without any restrictions will be discussed. To tell this story it is necessary to introduce the Koszul dual category: the category of marked curved Lie algebras and their morphisms.

# Monday afternoon, room CO1

## Kudryashov Alexei

**Topology and Combinatorics of Quasitoric Manifolds**

Motion group theory arose as a generalisation of Braid Group theory [1], [2]. The central idea is to understand possible motions of a (compact) submanifold within it's ambient manifold. In this talk, I will introduce the motion group Mot(n) of n ($\in \mathbb{N}$) disjoint, unlinked, unknotted loops in $\mathbb{R}^3$ (see for example [3],[4]). I will also state a classification theorem of particular unitary representations of this group.


[1] DM Dahm, A Generalization of Braid Theory, Ph.D. Thesis, Princeton University, 196

[2] D.L. Goldsmith, The theory of motion groups, Michigan Math. J. 28 (1981), 3-17.

[3] FWattenberg, Differentiable motions of unknotted, unlinked circles in 3space, Math. Scand 30 (1972) 107?135

[4] RL Rubinsztein, On the group of motions of oriented, unlinked and unknotted circles in R3, I, Preprint (2002)


## D'Mello Shane

**Chord Diagrams and Generic Real Rational Planar Curves of Degree 4**

We will give an elementary proof that the rigid isotopy classification of generic real rational curves of degree 4 in the plane can be reduced to the combinatorial classification of certain chord diagrams.

## Santander Egas Daniela

**Arc operads and the Moduli space of surfaces**

I will define systems of arcs in surfaces and describe the arc complex of a surface. Using these I will give a leisurely introduction to a model of the Moduli space of two dimensional cobordisms and a PROP structure on it. If time permits I will mention connections with other Models of the PROP of Moduli space of surfaces and compactifications of it.

## Ward Benjamin

**Moduli space actions and cyclic operads**

I will describe a combinatorial dg model for the homology of the open moduli spaces of punctured Riemann spheres. This model acts (in the operadic sense) on chain complexes computing e.g. string topology, cyclic cohomology of a Frobenius algebra, or equivariant cohomology of an $S^1$ space. We thus find homology operations old and new, as well as a homotopy invariant description of the chain level structures which produce these operations.

# Monday afternoon, room CO2

## Bello Hugo

**Splittings and products of topological abelian groups**

Let $H$, $X$ and $G$ be topological abelian groups. A short exact sequence $0 \to H \xrightarrow{\imath} X \xrightarrow{\pi} G \to 0$ is called an extension of topological abelian groups if both $\imath$ and $\pi$ are continuous and open homomorphisms when considered as maps onto their images. The set $\mathrm{Ext}(G, H)$ of all extensions of topological abelian groups of the form $0 \to H \xrightarrow{\imath} X \xrightarrow{\pi} G \to 0$ turns out to be an (abstract) abelian group when we endow it with the Baer sum.

The main result of this talk states that $\mathrm{Ext}(G, \mathbb{T}^\alpha \times \mathbb{R}^\beta) = 0$ where $\alpha$ and $\beta$ are arbitrary cardinal numbers and $G = \prod_{i \in I} G_i$ is a product of locally precompact abelian groups.

To prove this result we will start by obtaining several properties of the Ext group. We will show that $\mathrm{Ext}(G, \prod_{\alpha<\kappa} H_\alpha) \cong \prod_{\alpha<\kappa} \mathrm{Ext}(G, H_\alpha)$ where $\prod_{\alpha<\kappa} H_\alpha$ is a product of topological abelian groups, and that $\mathrm{Ext}(G, H) \cong \mathrm{Ext}(\varrho G, H)$ where $\varrho G$ is the Raĭkov completion of $G$ and $H$ is Čech-complete. Finally, we will use the notion of admissible subgroup and the previously mentioned properties to reduce the problem to the case of extensions of countable products of metrizable groups by $\mathbb{R}$ or $\mathbb{T}$.

## Stephan Marc

**Finite group actions on two-dimensional complexes**

We provide an introduction to the following open question in equivariant topology: does every finite group action on a contractible two-dimensional complex have a fixed point?

## Garaialde Oihana

**p-local finite groups and partial groups**

We introduce some objects known as p-local finite groups, which have both an algebraic and topological side. The algebraic structure resembles the $p$- local structure of a group and their classifying spaces possess homotopic properties similar to that of the $p$-completion of classifying spaces of finite groups. The aim is to give an overview of this theory that links the p-local structure of a group with the homotopy type of its classifying space. Moreover, we present the notion of a partial group as a tool to answer a question in $p$-local theory.

## Egger Philip

**Spectral sequences and nilpotence**

One of the main problems in algebraic topology is computing the homotopy groups of spheres. We will introduce and give examples of the use of spectral sequences developed by Adams, and then May, to compute these in a significant range. To find groups beyond that range, one must rely on infinite-periodic families of elements, which can be obtained by considering the $v_n$ self-maps of Devinatz-Hopkins-Smith. We will give examples of such families.

# Tuesday morning, room CO1

## Grigoriev Ilya

**Characteristic classes of manifold bundles**

Fix a smooth, closed manifold $M$. Loosely speaking, a manifold bundle with fiber $M$ over a space $X$ assigns a manifold diffeomorphic to $M$ to every point of $X$. For example, any diffeomorphism of $M$ gives rise to a manifold bundle with fiber $M$ over a circle (Hint: Start with $M \times [0,1]$ and glue the ends). There is a space, called BDiff $M$, that gives rise to all manifold bundles with fiber $M$ (surprisingly, it has a rather geometric description). The elements of the cohomology ring of BDiff $M$ are called "characteristic classes", and are the most promising invariants for studying manifold bundles. This story is analogous to the classical story about vector bundles. However, while the characteristic classes of vector bundles are very well understood, the characteristic classes of manifold bundles are far more mysterious, even when $M = \sum_g$ is a surface of genus $g$. I will describe the Madsen-Weiss theorem and Harer stability theorem that allow us to compute all the characteristic classes of surface bundles, but only in cohomological degrees that are far smaller than $g$. I will then talk about what happens in higher degrees, and what little we know about bundles with higher-dimensional fibers.

## West Michael

**Homotopy Decompositions of Gauge Groups over Klein Surfaces**

Let $P$ be a principal $G$-bundle over a space $X$, then the gauge group of $P$ is defined to be its (topological) group of automorphisms. A useful way to calculate some invariants of gauge groups is to decompose them, up to homotopy, as a product of other spaces usually involving $G$ and $X$. In this talk we will discuss decompositions of gauge groups of principal $G$-bundles associated to Real vector bundles in the sense of Atiyah.

## Wassermann Thomas

**Spin TQFTs and Anyons**

Spin topological quantum field theories are representations of a category of bordisms with spin structures in an appropriate symmetric monoidal ($n-$)category. I will explain how to build such theories and indicate the various connections they have to physics, in particular to anyonic theories, and other areas of maths such as conformal nets.

# Tuesday morning, room CO2

## Malkiewich Cary

**An introduction to cyclic sets and cyclotomic spectra**

I will give an overview of the theory of cyclic sets and cyclic spectra, and end by describing some very new developments. Cyclic sets are a combinatorial model for topological spaces with a circle action. I'll draw some pictures to help show how you can see the fixed points of this circle action directly. Then we'll introduce the cyclic bar construction, which takes each group G to a cyclic set whose realization is the space of maps of the circle into BG. This is an example of a "cyclotomic" space: for each finite subgroup of the circle, the fixed points of this space are actually homeomorphic to the original space. Finally, we'll describe how the same construction works in the category of orthogonal spectra, arriving at the new "norm" model for topological Hochschild homology (THH) described in the paper of Angeltveit et al. Hopefully there will be time for a few small, very explicit examples.

## Angelini-Knoll Gabriel

**THH of the connective cover of the $K(1)$-local sphere**

In the 1980's, Waldhausen proposed a program for computing algebraic $K$-theory of chromatic localizations of the sphere spectrum. The map from the algebraic $K$-theory of the $p$-local sphere to the $p$-local integers factors through the algebraic $K$-theory of the connective $E(n)$-local spheres. To begin the ascension up the tower, we want to compute algebraic $K$-theory of the connective $E(1)$-local sphere. From the point of view of trace methods, the first step is to compute topological Hochschild homology. After $p$-completion, the $E(1)$-local sphere is homotopy equivalent to the $K(1)$-local sphere. We therefore compute $V(1)$-homotopy of the topological Hochschild homology of the connective $K(1)$-local sphere. We compute this using a May-type THH spectral sequence developed by Andrew Salch.

## Ungheretti Massimiliano

**A dihedral version of the Jones isomorphism**

The Jones isomorphism relates Hochschild homology $HH_{-\bullet}(S^*X)$ and cohomology of the free loop space $H^\bullet(LX)$, for any simply connected space $X$. This and its $S^1$-equivariant version, have provided algebraic models for string topology. In work in progress, we use sim- ilar simplicial methods to explore the $O(2)$-equivariant case and give an isomorphism $DH_{-\bullet}(S^*X) \cong H^\bullet_{O(2)}(LX)$, involving a avour of dihedral homology.

# Tuesday afternoon, room CO1

## Penney Mark

**Homotopy Fixed Points and the Classification of 2D Topological Field Theories**

In this talk I will discuss a question in homotopy theory which arises when classifying topological field theories via the Cobordism Hypothesis. Namely, topological field theories for manifolds with a framing are classified by a particular homotopy type $X$ carrying a (homotopy) $O(n)$-action. Field theories for manifolds with arbitrary $G$-structure (where $G$ is a Lie group with a map to $O(n)$) are classified by the homotopy fixed point space of the induced $G$-action on $X$. The plan for the talk is to introduce these ideas concretely by considering only two dimensional field theories. This has the advantage of minimising the use of higher category theory while still capturing the important features. Time permitting I will discuss the extension of these ideas to higher dimensions.

## Catanzaro Michael

**A generalization of the Boltzmann distribution and Hodge theory**

In this talk, I'll discuss a generalized notion of the Boltzmann distribution. This arises naturally from the view point of physics when studying Langevin processes (Stochastic differential equations) on a manifold. Specifically, we study twisted Laplacians that are related to these dynamics, in much the same way that Witten used deformed Laplacians to study Morse theory. Taking the low noise (low temperature) limit, we arrive at a unique harmonic form for the twisted Laplacians, which naturally plays the role of the Boltzmann distribution. Studying such leads to an explicit formula for the Hodge decomposition of a cocycle, i.e. splitting a $k$-form into its exact, co-exact, and harmonic parts. I will provide background and motivation from a physics standpoint, and then prove this decomposition and discuss applications from a topological viewpoint.

## Zeidler Rudolf

**Positive scalar curvature and secondary index theory**

We will discuss secondary index invariants such as the higher $\rho$-invariant for a metric of positive scalar curvature (PSC) on a spin manifold. These have been used fruitfully in certain cases to distinguish PSC metrics up to concordance or bordism. We adopt the approach of Xie-Yu and use the $K$-theory of Yu's localization algebras as receptacles for secondary index invariants. In this setup, we will present a new construction of the higher $\rho$-invariant of a PSC metric using a certain description of $K$-theory for graded $C^*$-algebras due to Trout. This allows simple proofs of various product formulas (cf. arXiv:1412.0685). Product formulas will enable us to extend the reach of the higher $\rho$-invariant e.g. to non-compact manifolds via a secondary partitioned-manifold index theorem.

## Rust Dan

**The Strange Topology of Aperiodic Tilings and Their Cohomology**

Aperiodic tilings have become an important object of study, related to the recently discovered quasicrystals. Instead of studying a tiling in isolation, we introduce the 'tiling space' associated to a particular aperiodic tiling - a moduli space which codes many of the combinatorial and dynamical properties of the tiling. We are lead to ask how we can use methods from algebraic topology to identify and distinguish these space. We'll outline a method for calculating the Cech cohomology of these spaces via the construction of an inverse limit and apply this method to a family of 'multi-substitution' tilings called the Mixed Chacon tilings. We present the outline of a recent proof that the set of all Mixed Chacon tiling spaces form an uncountable collection of topologically distinct spaces, each pair distinguished by their cohomology groups.

# Tuesday afternoon, room CO2

## Beardsley Jonathan

**Thom Spectra and Coalgebraic Structure**

We define $E_n$ bialgebras, coalgebras and comodules in the infinity category of spectra and describe a theorem providing a large number of examples by way of Thom spectra. We indicate applications to homotopical descent theory, Tannakian realization problems, and a spectral sequence for computing the moduli space of torsors for a fixed spectral bialgebra.

## Konter Johan

**Obstruction theory for logarithmic ring spectra**

The Goerss-Hopkins obstruction theory is a very sensitive tool for detecting whether a certain $E_*$-algebra can be realized as the $E_*$-homology of an $E_\infty$-ring spectrum $X$. A classical application is the construction of the spectrum $Tmf$ where it is crucial that the obstructions vanish for smooth algebras. We set up a logarithmic obstruction theory which is supposed to vanish for log smooth algebras. This would allow us to build $Tmf(\Gamma)$ with level structures in cleaner way than before with the added benefit of endowing these ring spectra with logarithmic structures as introduced by Rognes, Sagave and Schlichtkrull.

## Heard Drew

**The $E_2$-term of the $K(n)$-local $E_n$ Adams spectral sequence**

Chromatic homotopy theory implies that the stable homotopy groups of a p-local finite spectrum $X$ can be reassembled from the homotopy groups of a certain sequence of localizations with respect to a generalized cohomology theory known as Morvava $K$-theory, $K(n)$. To compute these homotopy groups Devinatz and Hopkins have introduced a spectral sequence known as the $K(n)$-local $E_n$ Adams spectral sequence. Under certain restrictive conditions the $E_2$-term of this spectral sequence can be given as continuous group cohomology. We generalize previous known results by working in a category of $L$-complete comodules, and identify conditions for when we can identify the $E_2$-term as an Ext group in this category. We give conditions for when this Ext group can be identified with continuous group cohomology. This is joint work with Tobias Barthel.

## Gallauer Martin

**Traces in monoidal derivators**

A theorem of May states that traces in stable monoidal homotopy categories are additive in distinguished triangles. But how do they behave under more general homotopical operations? In order to investigate this question we define traces in closed monoidal derivators and establish some of their properties. In the stable setting we derive an explicit formula for the trace of the homotopy colimit over finite categories in which every endomorphism is invertible.

# Wednesday morning, room CO1

## Scolamiero Martina

**Multidimensional Persistence and Noise**

Multidimensional persistence is a method in topological data analysis which allows to compare various measurements on a data set. Within this method a dataset is represented by a functor from the poset of $r$-tuples of non negative real numbers to the category of vector spaces. Such functors are well behaved and we call them tame and compact. In this talk I will explain a way of comparing tame and compact functors based on the notion of a noise. This approach is based on the idea that in multidimensional persistence it is possible not only to choose properties of a dataset we want to study, for example by using filter functions, but also what should be neglected. I will also introduce an invariant for tame and compact functors we call the basic barcode. Finally, stability properties of the basic barcode and computational aspects will be addressed. (Joint work with W.Chachólski, A.Lundman, S. Öberg, R.Ramanujam)

## Filakovsky Marek

**Deciding whether two equivariant maps are homotopic**

We will show how the methods of computational algebra, algebraic topology and computer science can be combined to give algorithmic solutions to a classical problems such as to decide whether two equivariant maps $f, g$ between finite simplicial complexes $X, Y$ with an action of a finite group $G$ are homotopic.

Further, we will discuss applications of the results of computational equivariant algorithmic methods in computational topology related e.g. to Tverberg–type problems.

## Balchin Scott

**Developments in Topological Data Analysis**

Topological data analysis is traditionally used to study large data sets to infer structure from it. This data set is endowed with a metric of some description which gives a notion of distance which allows us to build the Rips complex. However, what about in the situation where we do not have a symmetric distance on our data, as you would in a directed graph with respect to the shortest path. In this talk we will suggest a way to deal with such problems. We will also consider how one could use orbifolds to analyse clustering methods on a set of data. This is based on an ongoing joint research project with Etienne Pillin.

# Wednesday morning, room CO2

## Zielenkiewicz Magdalena

**Goresky-Kottwitz-MacPherson graphs and their applications in equivariant cohomology**

Goresky-Kottwitz-MacPherson graphs provide a combinatorial tool to describe the $T$-equivariant cohmology ring for a class of spaces satisfying certain conditions ($GKM$ manifolds). The description via $GKM$ graphs involves only the $0-$ and $1-$dimensional orbits of the action. I will briefly introduce the concept of the $GKM$ graph and describe it's relation to the Borel model of equivariant cohomology, concentrating on examples (projective spaces, grassmannians, flag varieties). I will also sketch relations with symplectic geometry and moment maps for torus actions and show examples of computations which can be done using $GKM$ graphs.

## Burfitt Matthew

**Free loop cohomology of complete flag manifolds**

We will discusses the calculation of the cohomology of the free loops space of complete flag manifolds. To demonstrate this we will focus on the case of the complete flag of the special unitary group, as our primary example.

## Low Zhen Lin

**Cocycles in categories of fibrant objects**

Jardine introduced a very general notion of cocycle in categories with weak equivalences: very simply, a cocycle is a span where one of the legs is a weak equivalence. I will try to explain how to show that, for a category of fibrant objects (in the sense of Brown), Jardine's cocycle categories functorially compute the homotopy type of the hom-spaces in the simplicial localisation. This can be interpreted as a non-abelian version of Verdier's hypercovering theorem.

## Wednesday afternoon, room CO1

### George Nadareishvili

**Subcategory lattice of noncommutative spaces**

We will briefly describe the triangulated category of $C*$-algebras with the action of a topological space and how this amounts to a filtration of $C*$-algebras, in case of finite space with Alexandrov topology.

After, using rather intuitive generalization of K-theory and the universal coefficient theorem for it, we will classify the lattices of all localizing subcategories of such triangulated categories.

## Wednesday afternoon, room INF3

### Adams Henry

**Exercises for Gunnar Carlsson's lecture**

This exercise session will be a hands-on introduction to persistent homology in topological data analysis. We will use the Javaplex software package (http://appliedtopology.github.io/javaplex), which comes equipped with a tutorial with examples, exercises, and solutions. Two of the real datasets included in the tutorial are the three-circle model for optical image patches, and the conformation space of the cyclo-octane molecule (which is a Klein bottle glued to a sphere along two circles of singularities).

# Wednesday afternoon, room CO2

## Barma Abdoul Kader Yacouba

**Rational homotopy type of the space of immersions**

Let $M$ be a simply connected and compact $m$ dimensional manifold and $k$ an integer. In this talk we will show that the Betti numbers of each component of the space of immersions of $M$ in $\mathbb{R}^{m+k}$ have polynomial growth. The main tool of the proof is the construction of an explicit model of the components of space of immersions. We will prove that each component has the rational homotopy type of the product of Eilenberg Maclane space.

## Yeakel Sarah

**New chain rule for the homotopy calculus of functors**

In the homotopy calculus of functors, Goodwillie defined a way of assigning a Taylor tower of polynomial functors to a homotopy functor and identified the homogeneous pieces as being classified by certain spectra, called the derivatives of the functor. Arone and Ching showed that the derivatives of the identity functor of spaces form an operad, and developed a chain rule for composable functors. We will review this theory and these results and show that through a slight modification to the definition of derivative, we can find a more straight forward chain rule for endofunctors of spaces.

## Tebbe Amelia

**Computing the Goodwillie-Taylor Tower for Atomic Discrete Modules**

Atomic discrete modules are functors from finite sets to chain complexes of $R$-modules that are completely determined by their value at a particular set. Robinson gave an explicit bicomplex for computing the stable homology of a general discrete module, i.e. functor from finite sets to chain complexes of $R$-modules. For a discrete module, there is a filtration by atomic discrete modules constructed from left Kan extensions. The rows of Robinson's bicomplex are the stable homology of these associated atomic discrete modules.

## Prasma Matan

**The Grothendieck Construction for Model Categories**

The stable homology of a functor is the homology of the Goodwillie derivative of the functor. This fact inspires us to extend Robinson's bicomplex to one for computing the higher order polynomial approximations produced by Goodwillie's calculus of functors. To this end, we give an explicit bicomplex for atomic functors such that truncation by rows allow us to compute the Goodwillie polynomial approximations. The Grothendieck construction is a classical correspondence between diagrams of categories and coCartesian fibrations over the indexing category. In this paper we consider the analogous correspondence in the setting of model categories. As a main result, we establish an equivalence between suitable diagrams of model categories indexed by $\mathcal{M}$ and a new notion of **model fibrations** over $\mathcal{M}$. When $\mathcal{M}$ is a model category, our construction endows the Grothendieck construction with a model structure which gives a presentation of Lurie's $\infty$-categorical Grothendieck construction and enjoys several good formal properties. We apply our construction to various examples, yielding model structures on strict and weak group actions and on modules over algebra objects in suitable monoidal model categories.

# Thursday morning, room CO1

## Otter Nina

**The phylogenetic operad**

We construct an operad Phyl whose operations are the edge-labelled trees used in phylogenetics. This operad is the coproduct of Com, the operad for commutative semigroups, and $[0, \infty)$, the operad with unary operations corresponding to nonnegative real numbers, where composition is addition. We show that the Markov models used to reconstruct phylogenetic trees from genome data give coalgebras of Phyl. These always extend to coalgebras of the larger operad Com+$[0, \infty]$, since Markov processes on finite sets converge to an equilibrium as time approaches infinity. We show that for any operad $O$, its coproduct with $[0, \infty]$ contains the Boardman-Vogt operad $W(O)$. (Joint work with John Baez)

## Kalisnik Verovsek Sara

**Parametrized homology and Parametrized Alexander Duality Theorem**

An important problem with sensor networks is that they do not provide information about the regions that are not covered by their sensors. If the sensors in a network are static, then the Alexander Duality Theorem from classic algebraic topology is sufficient to determine the coverage of a network. However, in many networks the nodes change position over time. In the case of dynamic sensor networks, we consider the covered and uncovered regions as parametrized spaces with respect to time. I will discuss parametrized homology, a variant of zigzag persistent homology, which measures how the homology of the level sets of a space changes as the parameter varies. I will show also how we can extend the Alexander Duality theorem to the setting of parametrized homology. This approach sheds light on the practical problem of 'wandering' loss of coverage within dynamic sensor networks.

## Belchi Francisco

**$A$-infinity structures and Persistent Homology**

I will try to mix the spirit of this year's two minicourses by giving some ideas on how to combine $A$-infinity structures with Persistent Homology.

# Thursday morning, room CO2

## Weighill Thomas

**A characterisation of $R_1$-spaces via a Mal'tsev condition**

In this talk we describe a connection between the notion of a Mal'tsev category [1] from categorical algebra and a separation axiom from topology. A Mal'tsev category can be defined as a category $C$ such that for every object $S$ in $\mathbb{C}$, the functor $Hom(S, -)$ maps every internal relation in $\mathbb{C}$ to a difunctional relation. Regular Mal'tsev categories provide an important axiomatic context for the study of groups and group-like structures for example, every semi-abelian category [3] is such. It is well known that the category **Top** is not regular, but that its dual, $\mathbf{Top}^{op}$, is. However, $\mathbf{Top}^{op}$ is not a Mal'tsev category. In this talk, we first show that every regular category with binary coproducts (of which $\mathbf{Top}^{op}$ is an example) contains a largest full subcategory $M$ which is Mal'tsev and closed under colimits and regular quotients. We then show that in the case of $\mathbf{Top}^{op}$, $M$ turns out to be the full subcategory of $R_1$-spaces in the sense of Davis [2], i.e. spaces in which topologically distinguishable points are separated by neighbourhoods (also known in the literature as preregular spaces).

[1] A. Carboni, J. Lambek, and M. C. Pedicchio, Diagram chasing in Mal'cev categories, J. Pure Appl. Algebra 69, 1990, 271-284.

[2] A. S. Davis, Indexed Systems of Neighborhoods for General Topological Spaces, The American Mathematical Monthly 68, 1961, 886-893.

[3] G. Janelidze, L. Márki and W. Tholen, Semi-abelian categories, J. Pure Appl. Algebra 168, 2002, 367-386.

## Dungan Ivan

**'n-Butterflies: Modeling Morphisms between Strict n-Groups**

2-Groups can be modeled by algebraic objects known as crossed modules; however, homotopy theory must be applied to model the morphisms of 2-groups by the morphisms of crossed modules. Behrang Noohi defined purely algebraic objects called butterflies which model morphisms of 2-groups while avoiding the topological techniques. Reduced n-crossed complexes are algebraic objects which generalize crossed modules and model strict $n$-groups. We will discuss a generalization of butterflies to reduced $n$-crossed complexes.

## Schaeppi Daniel

**Tannaka duality and Adams Hopf algebroids**

Classical Tannaka duality is a duality between groups and their categories of representations. It answers two basic questions: can we recover the group from its category of representations, and can we characterize categories of representations abstractly? These are often called the reconstruction problem and the recognition problem. In the context of affine group schemes over a field, the recognition problem was solved by Saavedra and Deligne using the notion of a (neutral) Tannakian category.

This can be generalized to the context of Adams Hopf algebroids and their categories of comodules. Using the language of stacks, this generalization gives a duality between Adams stacks and their categories of quasi-coherent sheaves. I will start with an overview of classical Tannaka duality and its generalization, and I will conclude my talk with an outline how this duality can be used to interpret various geometric constructions involving Adams stacks in terms of their associated categories.

# Friday morning, CO1

## Reeh Sune

**Saturated fusion systems as stable retracts of groups**

A saturated fusion system associated to a finite group $G$ encodes the $p$-structure of the group as the Sylow $p$-subgroup enriched with additional conjugation. The fusion system contains just the right amount of algebraic information to for instance reconstruct the $p$-completion of $BG$, but not $BG$ itself. Abstract saturated fusion systems $F$ without ambient groups exist, and these have ($p$-completed) classifying spaces $BF$ as well. In spectra, the suspension spectrum of $BF$ becomes a retract of the suspension spectrum of $BS$, for the Sylow $p$-subgroup $S$, so $BF$ gets encoded as a characteristic idempotent in the double Burnside ring of $S$. This way of looking as fusion systems as stable retracts of their Sylow $p$-subgroups is a very useful tool for generalizing theorems from groups or $p$-groups to saturated fusion systems. In joint work with Tomer Schlank and Nat Stapleton, we use this retract approach to do Hopkins-Kuhn-Ravenel character theory for all saturated fusion systems by building on the theorems for finite p-groups.

## Molinier Rémi

**Classifying spaces of saturated fusion systems and their cohomology**

A saturated fusion system is a small category which can, for example, encode how a finite group $G$ acts on its $p$-subgroups by conjugation. We can then, as for a finite group, define a classifying space of a saturated fusion system and look at its cohomology. It is well known that the cohomology of the classifying space of a finite group is isomorphic to the cohomology of the group itself. Here we will see that this can be extended to the classifying space of a saturated fusion system.

## Araujo Manuel

**Fusion categories and 3-dimensional topological field theories**

I will give a general overview of the connection between fusion categories and $3d$ TFT, as described below. Given a spherical fusion category, one can build an invariant of oriented 3-manifolds, called the Turaev-Viro invariant. The constructions proceeds by labeling triangulations of the 3-manifold by objects and morphisms in the category and using the graphical calculus to extract numbers. Given a modular tensor category, there is another construction that produces an invariant of oriented 3-manifolds, called the Reshetikin-Turaev invariant. It is based on a presentation of the 3-manifold by surgery on a link in $S^3$ and again depends on the existence of a graphical calculus for modular tensor categories. The center $Z(C)$ of a spherical fusion category $C$ is a modular tensor category. Balsam and Kirilov proved that the Turaev-Viro invariant corresponding to $C$ agrees with the Reshetikin-Turaev invariant corresponding to $Z(C)$. A more recent perspective on this subject is given by the cobordism hypothesis, which is a statement about fully extended field theories. In our case, this means field theories defined on manifolds of dimensions $0, 1, 2$ and 3. Using the cobordism hypothesis, one can prove that spherical fusion categories actually provide fully extended oriented field theories. So it's natural to ask whether the fully extended oriented field theory associated to a spherical fusion category via the cobordism hypothesis recovers the Turaev-Viro invariant.

# Friday morning, room CO2

## Le Grignou Brice

**From homotopy operads to infinity-operads**

The goal of the talk is to compare two notions of operads up to homotopy which appear in the literature. Namely, we construct a functor from the category of strict unital homotopy colored operads to the category of infinity-operads. The former notion, that we introduce, is the operadic generalization of the notion of $A$-infinity-categories and the latter notion was defined by Moerdijk-Weiss in order to generalize the simplicial notion of infinity-category of Joyal-Lurie. This functor extends in two directions the simplicial nerve of Faonte-Lurie for $A$-infinity-categories and the homotopy coherent nerve of Moerdijk-Weiss for *dg* operads. Finally we show that this functor has some good homotopical properties with respect to the Cisinski-Moerdijk model structure on dendroidal sets.

## White David

**The Baez-Dolan Stabilization Hypothesis and Left Proper Model Structures on Operads**

We will begin with an overview of an old problem, due to Baez and Dolan, and discuss where in the solution of this problem model category theoretic considerations arise. This discussion will relate TQFTs, higher category theory, Rezk's Theta n spaces, model categories, and operads. The solution requires placing left proper model structures on algebras over certain colored operads, most notably on the category of non-reduced symmetric operads. We will discuss how this can be accomplished and why left properness is so essential.

## Balzin Eduard

**Derived sections and categorical resolutions in homotopical context** (arXiv:1410.3387)

For triangulated categories, there is a fairly useful notion of a categorical resolution (of singularities, as defined by Kuznetsov and Luntz). One might ask if the principal aspects of this notion can be generalised to the setting of homotopical algebraic structures such as, for instance, categories of $E_n$-algebras and the like. If one describes algebraic structures using a Segal-inspired approach, the question can be then transferred to the setting of Grothendieck fibrations with a homotopical structure. We introduce our notion of a derived section of a homotopical Grothendieck fibration, which appears to be a meaningful piece of technology to consider in its own right, and then show that a selected class of base functors gives rise to categorical resolutions for homotopical categories of derived sections.