# Topology Workshop LIGAT CRM RP 2019

**Centre de Recerca Matemàtica**

**June 17th – 20th, 2019**

## Organizing Committee

Carles Broto, Universitat Autònoma de Barcelona
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# Contents

# 1. Schedule

| **Monday, 17th of June 2019** | |
|---|---|
| 09:30–09:50 | Registration |
| 10:00–11:00 | Jesper Grodal, University of Copenhagen<br>*String topology of finite groups of Lie type* |
| 11:00–11:30 | Coffee Break |
| 11:30–12:30 | Jelena Grbić, University of Southampton<br>*The homotopy theory of polyhedral products* |
| 12:30–14:30 | Lunch |
| 14:30–15:30 | Alejandro Adem, The University of British Columbia<br>*Free Finite Group Actions on Rational Homology Spheres* |
| 15:30–16:00 | Coffee Break |
| 16:00–16:50 | Ergün Yalçın, Bilkent University<br>*Obstructions for gluing biset functors* |
| 17:00–17:50 | Irakli Patchkoria, University of Aberdeen<br>*On Witt vectors with coefficients* |
| **Tuesday, 18th of June 2019** | |
| 09:00–09:50 | Andrés Angel, Universidad de los Andes<br>*Non-representables classes and stratifolds* |
| 09:50–11:00 | Stefan Schwede, Universität Bonn<br>*Categories and orbispaces* |
| 11:00–11:30 | Coffee Break |
| 11:30–12:30 | David Chataur, Université de Picardie Jules Verne<br>*From exit paths to intersection cohomology* |
| 12:30–14:30 | Lunch |
| 14:30–15:30 | Natàlia Castellana, Universitat Autònoma de Barcelona<br>*Modules over cochains of classifying spaces* |
| 15:30–16:00 | Coffe Break |
| 16:00–16:50 | Tobias Barthel, Københavns Universitet<br>*The affine line in tensor triangular geometry* |

| **Wednesday, 19th of June 2019** | |
|---|---|
| 09:00–09:50 | Tyrone Cutler, Universität Bielefeld<br>*The Homotopy Types of Certain Spinor Gauge Groups Over* $S^4$ |
| 10:00–11:00 | Bob Oliver, Université Paris 13<br>*The loop space homology of a small category* |
| 11:00–11:30 | Coffee Break |
| 11:30–12:30 | Magdalena Kędziorek, Universiteit Utrecht<br>*Homotopical Galois extensions of* $E_\infty$*-algebras* |
| 12:30–14:30 | Lunch |
| **Thursday, 20th of June 2019** | |
| 10:00–11:00 | Markus Banagl, Universität Heidelberg<br>*Gysin Transfers, the Goresky-MacPherson L-Class and Mixed Hodge Theory* |
| 11:00–11:30 | Coffee Break |
| 11:30–12:30 | Ivo Dell'Ambrogio, Université de Lille<br>*Additive derivators and canonical norm maps* |
| 13:00–14:30 | Lunch |
| 14:30–15:30 | L. J. Hernández, Universidad de la Rioja<br>*Homotopy of exterior spaces and discrete semi-flows* |
| 11:00–11:30 | Coffee Break |
| 16:30–17:30 | Wolfgang Pitsch, Universitat Autònoma de Barcelona<br>*Conjugation Spaces* |

# 2. Abstracts of the Plenary Talks

## 2.1. ***Free Finite Group Actions on Rational Homology Spheres.***

**Alejandro Adem, University of British Columbia**
***E-mail address:*** adem@math.ubc.ca.

We use methods from the cohomology of groups to describe the finite groups which can act freely and homologically trivially on closed 3-manifolds which are rational homology spheres. We also discuss the related question of which finite groups can arise as fundamental groups of rational homology 4-spheres.

This is joint work with I. Hambleton.

## 2.2. ***The affine line in tensor triangular geometry.***

**Tobias Barthel, University of Copenhagen**
***E-mail address:*** tbarthel@math.ku.dk.

Inspired by the pioneering work of Hopkins, Neeman, and Thomason on the classification of thick subcategories of perfect complexes, Balmer constructs for any essentially small tensor triangulated category $\mathcal{T}$ a locally-ringed space $\mathrm{Spc}(\mathcal{T})$ which encodes the global structure of $\mathcal{T}$. The subject of tensor triangular geometry is then to further our understanding of the subtle interplay between $\mathrm{Spc}(\mathcal{T})$ and $\mathcal{T}$ abstractly as well as for prominent examples of tensor triangulated categories.
The goal of this talk is to report on joint work in progress with Schlank and Stevenson which revisits and extends Balmer's framework, by introducing the analogue of affine schemes in the context of (higher) tensor triangular geometry. In particular, we will construct and study the affine line.

## 2.3. ***Gysin Transfers, the Goresky-MacPherson L-Class and Mixed Hodge Theory.***

**Markus Banagl, Universität Heidelberg**
***E-mail address:*** banagl@mathi.uni-heidelberg.de.

Hirzebruchs L-class is well-known to occupy a central role in the topological classification of high-dimensional manifolds. The L-class of singular spaces, constructed by Goresky and MacPherson, can be assigned a similar role, but much less is known about its behavior, and only a relatively small number of concrete calculations have been carried out. The behavior of this class under Gysin transfers has only recently been understood; the proofs rely on Ranicki's symmetric L-theory, Siegel's Witt bordism, L-homology orientations for singular spaces introduced by Banagl-Laures-McClure, and various blocked bundle theories, notably the Buoncristiano-Rourke-Sanderson theory of mock bundles. These results have bearings on characteristic classes defined through mixed Hodge modules that we hope to address.

2.4. ***Modules over cochains of classifying spaces.***

**Natàlia Castellana, Universitat Autònoma de Barcelona**
***E-mail address:*** natalia@mat.uab.cat.

Given a topological space $X$, geometric cochains on $X$ with coefficients in a field $k$ are defined to be the function spectrum $C^*(X;k) = F(\Sigma^\infty_+ X, Hk)$ where $Hk$ is the Eilenberg-MacLane spectrum. This is a commutative ring spectrum. If $R$ is a commutative ring spectrum, the category $\mathrm{Mod}_R$ of modules over $R$ is a tensor triangulated category. When $X$ is the classifying space of a compact connected Lie group, Benson and Greenlees proved that the category of modules is stratified. In this joint work with T. Barthel, D. Heard and G. Valenzuela we show that stratification theorems on the classification of localizing and thick subcategories hold in a larger variety of examples when $X$ is a classifying space for a group or a fusion system on a finite $p$-group.

References

[1] T. Barthel, N. Castellana, D. Heard, and G. Valenzuela Stratification and duality for homotopical groups arXiv:1711.03491
[2] T. Barthel, N. Castellana, D. Heard, and G. Valenzuela On stratification for spaces with Noetherian mod $p$ cohomology arXiv:1904.12841

2.5. ***From exit paths to intersection cohomology.***

**David Chataur, LAMFA, Université de Picardie**
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Let $X$ be a "nice" topological space, the category of $\pi_1(X)$-sets is equivalent to the category of locally constant sheaves of sets on $X$. A similar result has been proven by R. MacPherson for constructible sheaves on a stratified space $S$ in terms of representations of the category of exit paths $\mathbf{Exit}(S)$. Such result is motivated by the study of perverse sheaves.
Recently an $(\infty,1)$-category of exit paths has been introduced and studied by J. Lurie in order to get higher categorical versions of R. MacPherson's result on exit paths.
In this talk I plan to explain how this higher categorical version of the category of exit paths enables a homotopical treatment of Goresky-MacPherson Intersection cohomology.

This is joint work with Martin Saralegui (Artois) and Daniel Tanré (Lille).

2.6. ***Additive derivators and canonical norm maps.***
**Ivo Dell'Ambrogio, Université de Lille**
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Let $\mathcal{D}$ be an *additive derivator*, that is, a contravariant 2-functor from the 2-category of small categories ("diagram shapes") to the (very large) 2-category of additive categories, satisfying a few nice properties; among these, there exists a left adjoint $f_!$ and a right adjoint $f_*$ for the "restriction functor" $f^* = \mathcal{D}(f)$ along any functor $f$ of small categories.
In joint work with Paul Balmer [1, §4.1] we proved, without any recourse to models, that there exists a canonical "Wirthmüller-style" natural isomorphism

$$\Theta_i \colon i_! \xrightarrow{\sim} i_*$$

between adjoints if $i\colon H \to G$ is a faithful functor of finite groupoids, e.g., the inclusion of a subgroup. Moreover, the collection of all $\Theta_i$ satisfies a list of nice properties which characterize it uniquely.
In recent joint work with Viet-Cuong Pham, we show how to use the inverses $\Theta_i^{-1}$ in order to define a "norm map"

$$N_G \colon p_! \longrightarrow p_*$$

for the projection $p\colon G \to 1$ of any finite group $G$ to the trivial group. By specializing to the derivator $\mathcal{D}$ of stable homotopy, so that $\mathcal{D}(1)$ is the stable homotopy category and $\mathcal{D}(G)$ the category of "very naive $G$-spectra" $X$ (i.e. $G$-shaped diagrams of spectra), we obtain this way a canonical, well-behaved, and model-free construction of the norm map $X_{hG} \to X^{hG}$ from homotopy orbits to homotopy fixed points.

## References

[1] Paul Balmer, Ivo Dell'Ambrogio. *Mackey 2-functors and Mackey 2-motives.* Preprint 2019, arXiv:1808.04902.

2.7. ***The homotopy theory of polyhedral products.***
**Jelena Grbić, University of Southampton**
***E-mail address:*** j.grbic@soton.ac.uk.

Toric topology is the study of topological spaces with well behaved toric symmetries. The subject was first identified about 20 years ago and has developed rapidly, with remarkably varied input from cobordism and homotopy theory, algebraic and combinatorial geometry, commutative algebra, and symplectic geometry and integrable systems.
Moment-angle complexes are spaces formed by gluing together products of discs and circles according to a recipe determined by an underlying simplicial complex. The construction of moment–angle complexes unifies several existing constructions from seemingly unrelated areas of mathematics, including: the intersection

of special real and Hermitian quadrics studied in topology and holomorphic dynamics, level sets for moment maps in the construction of Hamiltonian toric manifolds via symplectic reduction, and complements of coordinate subspace arrangements.

A polyhedral product is a functorial generalisation of a moment-angle complex in which the discs and circles are replaced by $CW$-pairs. Polyhedral products extend the unifying reach of moment-angle complexes to include: the Whitehead filtration in homotopy theory, the study of asphericity in group cohomology, the study of right-angled Artin groups, right-angled Coxeter groups and graph products in geometric group theory, identities relating the Euler $\phi$–function to the Möbius function, and the study of robotics and arachnid mechanisms. I plan to survey the development of the homotopy theory of polyhedral products.

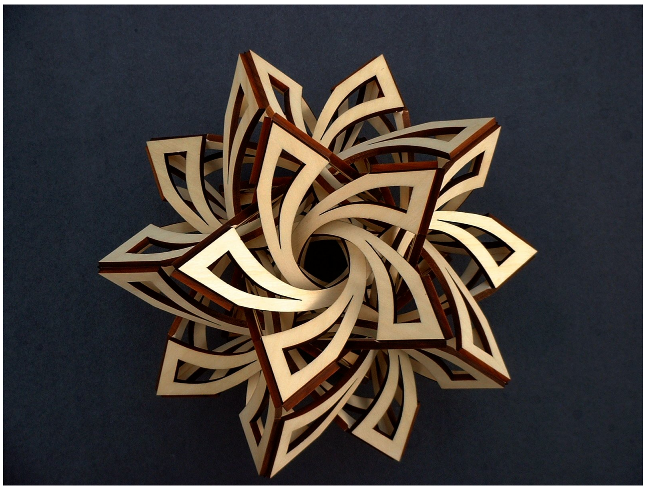

FIGURE 1. Frabjous by George Hart

2.8. ***String topology of finite groups of Lie type.***

**Jesper Grodal, University of Copenhagen**
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Finite groups of Lie type, such as $\mathrm{SL}_n(\mathbb{F}_q)$, $\mathrm{Sp}_n(\mathbb{F}_q)$..., are ubiquitous in mathematics, and calculating their cohomology has been a central theme over the years.

Without any structural reasons as to why, it has calculationally been observed that, when calculable, their mod $\ell$ cohomology agree with $H^*(LBG(\mathbb{C});\mathbb{F}_\ell)$, the mod $\ell$ cohomology of the free loop space on $BG(\mathbb{C})$, the classifying space of the corresponding complex algebraic group $G(\mathbb{C})$, as long as $q$ is congruent to 1 mod $\ell$. This despite that $LBG(\mathbb{C})$ and $BG(\mathbb{F}_q)$ are vastly different spaces, also at a prime $\ell$, ruling out some space-level equivalence.

In recent joint work with Anssi Lahtinen [1], that combines $\ell$–compact groups with string topology à la Chas–Sullivan, we give a general structural relationship between these two cohomologies, which, suitably formulated, even works without any congruence condition on $q$, as long as it is prime to $\ell$. We use this to prove structured versions of previous calculations, and establish isomorphism in new cases. The isomorphism conjecture in general hinges on the fate of a single cohomology class. My talk will begin to tell this story, as we know it so far...

### References

[1] Jesper Grodal and Anssi Lahtinen: String topology of finite groups of Lie type. Preprint.

### 2.9. *Homotopical Galois extensions of $E_\infty$-algebras.*

**Magdalena Kędziorek, Utrecht University**
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Rognes generalised the classical notion of Galois extensions from algebra to homotopy theory of ring spectra. In work with Beaudry, Hess, Merling and Stojanoska we discussed a general formal framework in which the notion of (homotopical) Galois extensions can be studied and we applied that work to the motivic homotopy theory. In this talk I will recall the general framework for homotopical Ga- lois extensions and present an ongoing work with Hess on homotopical Galois theory for $E_\infty$-algebras.

### 2.10. *The loop space homology of a small category.*

**Bob Oliver, Université Paris 13**
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In an article published in 2009, Dave Benson described, for a finite group $G$, the mod $p$ homology of the space $\Omega(BG^\wedge_p)$ — the loop space of the $p$-completion of $BG$ — in purely algebraic terms. In joint work with Carles Broto and Ran Levi, we have tried to better understand Benson's result by generalizing it. Among other things, we showed that when $\mathcal{C}$ is a small category, $|\mathcal{C}|$ is its geometric realization, $R$ is a commutative ring, and $|\mathcal{C}|^+_R$ is a plus construction of $|\mathcal{C}|$ with respect to homology with coefficients in $R$, then $H_*(\Omega(|\mathcal{C}|^+_R); R)$ is the homology any chain complex of projective $R\mathcal{C}$-modules that satisfies certain conditions. Benson's theorem is then the special case where $\mathcal{C}$ is the category associated to a finite group $G$ and $R = \mathbb{F}_p$, so that $p$-completion appears as a special case of the plus construction.

2.11. ***On Witt vectors with coefficients.***
**Irakli Patchkoria, University of Aberdeen**
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We introduce Witt vectors for (non-commutative) rings with coeffcients in bimodules. We show that the components of the Hill-Hopkins-Ravanel norm for cyclic p-groups is isomoprhic to a truncation of the p-typical Witt vectors of integers with suitable coefficients. More generally we compute the group of componets of the Lindenstrauss-McCarthy TR spectra and identify it with Witt vectors with coefficients. On the algebraic side our construction generalizes Hesselholt's Witt vectors for non-commutative rings and Kaledin's polynomial Witt vectors for vector spaces over perfect fields of positive characteristic. This is all joint with E. Dotto, A. Krause and T. Nikolaus.

References

[1] L. Hesselholt, Witt vectors of non-commutative rings and topological cyclic homology, Acta Mathematica 178 (1997), 109–141.
[2] M. Hill, M. Hopkins, D. Ravenel, On the nonexistence of elements of Kervaire invariant one. Annals of Mathematics 184 (2016), no. 1, 1–262.
[3] D. Kaledin, Witt vectors as a polynomial functor, Selecta Mathematica 24, no. 1 (2018), 359–402.
[4] A. Lindenstrauss, R. McCarthy, On the Taylor tower of relative K-theory, Geometry and Topology 16, no. 2 (2012), 685–750.

2.12. ***Conjugation Spaces.***
**Wolfgang Pitsch, Universitat Autònoma de Barcelona**
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Conjugations spaces where introduced by V. Puppe in his research on asymmetric manifolds, they where further studied in an eponymus work by Hausmann, Holm and Puppe showing that these spaces abund in deiferent contexts. Roughly speaking a conjugation space is a topological space $X$ with an involution $\tau$ such that the fixed points $X^\tau$ have the same cohomology with $\mathbb{Z}_2$ coefficients as $X$ but with degrees divided by two. One furthermore requires that these cohomologies are related by a conjugation equation that comes from considering the Borel cohomology of $X$ and $X^\tau$. The prototypical example is that of the projective spaces $\mathbb{R}P^n \subset \mathbb{C}P^n$. In this talk we will show that beeing a conjugation space has a very natural interpretation in equivariant cohomology: a topological space $X$ with a conjugation $\tau$ is conjugation space if and only if the equivariant spectrum $X \wedge H\underline{\mathbb{F}}$, viewed as an $H\underline{\mathbb{F}}$-module, splits as a wedge of suspensions of $H\underline{\mathbb{F}}$ along the regular representation of $\mathbb{Z}_2$. Here $H\underline{\mathbb{F}}$ denotes the equivariant Eilenberg-Maclane spectrum associated to constant $\mathbb{Z}_2$ coefficients.

This is joint work with N. Ricka and J. Scherer.

### 2.13. *Categories and orbispaces.*

**Stefan Schwede, Mathematisches Institut, Universität Bonn**
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Constructing and manipulating homotopy types from categorical input data has been an important theme in algebraic topology for decades. Every category gives rise to a 'classifying space', the geometric realization of the nerve. Up to weak homotopy equivalence, every space is the classifying space of a small category. More is true: the entire homotopy theory of topological spaces and continuous maps can be modeled by categories and functors. The aim of this talk is to explain a vast generalization of the equivalence of the homotopy theories of categories and spaces: small categories represent refined homotopy types of orbispaces whose underlying coarse moduli space is the traditional homotopy type hitherto considered.

A *global equivalence* is a functor $\Phi : \mathcal{C} \to \mathcal{D}$ between small categories with the following property: for every finite group $G$, the functor $G\Phi : G\mathcal{C} \to G\mathcal{D}$ induced on categories of $G$-objects is a weak equivalence. These global equivalences are part of a model structure on the category of small categories, which is moreover Quillen equivalent to the homotopy theory of orbispaces in the sense of Gepner and Henriques. Every cofibrant category in this global model structure is opposite to a *complex of groups* in the sense of Haefliger.

#### References

[1] S. Schwede, *Categories and orbispaces*, to appear in Algebraic & Geometric Topology arxiv:1810.06632

## 3. Abstracts of the Contributed Talks

### 3.1. *Non-representables classes and stratifolds.*

**Andrés Angel, Universidad de los Andes**
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A natural problem in algebraic topology is Steenrod's representability problem: Is every homology class of a space the pushforward of the fundamental class of a closed manifold?. This question was solved by Rene Thom: Every homology class with $\mathbb{Z}/2\mathbb{Z}$-coefficients is representable, but there are homology classes with $\mathbb{Z}$-coefficients that are not representable.
Dennis Sullivan introduced $\mathbb{Z}/k\mathbb{Z}$-manifolds, example of manifolds with singularities, to study index problems (with $\mathbb{Z}/k\mathbb{Z}$-coefficients). Every $\mathbb{Z}/k\mathbb{Z}$-manifold has a fundamental class with $\mathbb{Z}/k\mathbb{Z}$-coefficients and the Steenrod representability problem in this case is the question: Is every homology class with $\mathbb{Z}/k\mathbb{Z}$-coefficients the pushforward of the fundamental class of a $\mathbb{Z}/k\mathbb{Z}$-manifold? The answer to this question is also negative.
Matthias Kreck introduced stratifolds, a theory of smooth stratified spaces to represent homology with $\mathbb{Z}$ and $\mathbb{Z}/2\mathbb{Z}$-coefficients as bordism theories.
I will introduce $\mathbb{Z}/k\mathbb{Z}$-stratifolds to represent homology with $\mathbb{Z}/k\mathbb{Z}$-coefficients, and give explicit geometric descriptions of the non-representable classes of Thom and non-representable classes with $\mathbb{Z}/k\mathbb{Z}$-coefficients. In particular we can explain how the singularities look like.
By working with stratifolds and $\mathbb{Z}/k\mathbb{Z}$-stratiflods we can understand the Atiyah-Hirzebruch spectral sequence for oriented bordism and $\mathbb{Z}/k\mathbb{Z}$-bordism respectively and explain why the singularities of the non-representable classes we constructed cannot be removed.

Joint work with Carlos Segovia and Fernando Arley Torres.

#### References

[1] A. Angel, C. Segovia y F. Torres. *$\mathbb{Z}_k$-stratifolds.* arXiv:1810.00531.

### 3.2. *The Homotopy Types of Certain Spinor Gauge Groups Over $S^4$.*

**Tyrone Cutler, Universität Bielefeld**
***E-mail address:*** tcutler@math.uni-bielefeld.de.

The gauge group $\mathcal{G}$ of a principal $G$-bundle $P \to X$ is the group of all $G$-equivariant bundle automorphisms covering the identity on $X$. If $G$ is a compact, connected Lie group then $\mathcal{G}$ will in general be an infinite-dimensional Lie group. However much of its topological structure will be dictated by the topological features of the base space $X$ and by the group-theoretic properties of $G$. In particular, when $X = S^n$, the homotopy-commutativity of $G$ plays a direct role in determining the number of distinct homotopy types amongst all the possible

$G$-gauge groups - a number which will in fact be finite for such $G$ and $X$ according to a result of Crabb and Sutherland, despite the fact that the number of bundle-isomorphism classes may be infinite.
In this talk I will discuss recent work relating to the homotopy types of $Spin(6) \cong SU(4)$- and $Spin(7)$-gauge groups over $S^4$. The first part of this work is joint with Stephen Theriault. We completely determine the number of $p$-local homotopy types amongst these gauge groups for $p$ an odd prime, and give strict bounds on the number of 2-local homotopy types. Many of the interesting features of a typical calculation of this sort will be discussed and highlighted.

### 3.3. ***Homotopy of exterior spaces and discrete semi-flows.***

**L. J. Hernández, Universidad de la Rioja**
***E-mail address:*** luis-javier.hernandez@unirioja.es.

An exterior space is a topological space provided with a quasi-filter of open subsets (closed by finite intersections). For an exterior space one can consider limits, bar-limits and different sets of end points (Steenrod, Čech, Brown-Grossman).
In this work we analyze relations between exterior spaces and discrete semi-flows. In order to do this we introduce the notion of exterior discrete semi-flow, which is a mixture of exterior space and discrete semi-flow. We see that any classical discrete semi-flow can be provided with the structure of an exterior discrete semi-flow by taking the quasi-filter of right-abosrbing open subsets. Such a family of open subsets is used to study the relations between limits and periodic points and connections between bar-limits and omega-limits. The different notions of end points are used to decompose the region of attraction of an exterior discrete semi-flow as a disjoint union of basins of end points. We also analyze the exterior discrete semi-flow structure induced by the family of open neighborhoods of a given sub-semi-flow.

### 3.4. ***Obstructions for gluing biset functors.***

**Ergün Yalçın, Bilkent University**
***E-mail address:*** yalcine@fen.bilkent.edu.tr.

We develop an obstruction theory for the existence and uniqueness of a solution to the gluing problem for a destriction functor defined on subquotients of a finite group $G$ and apply it to some well-known $p$-biset functors, such as the Burnside ring functor, the rational representation ring functor, the Dade group functor at odd primes. The obstruction groups for this theory are the reduced cohomology groups of a category $\mathcal{D}_G$ whose objects are the sections $(U, V)$ of $G$, where $1 \neq V \trianglelefteq U \leq G$, and whose morphisms are defined as a generalization of morphisms in the orbit category. Using this obstruction theory, we calculate the obstruction group for the Dade group of a $p$-group when $p$ is odd.

This is a joint work with Olcay Coşkun [1].

#### References

[1] O. Coşkun and E. Yalçın, Obstructions for gluing biset functors, preprint, (arXiv:1807.01107).

## 4. List of Participants

| | |
|---|---|
| Alejandro Adem | The University of British Columbia |
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| Carles Broto | Universitat Autònoma de Barcelona |
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