

**IGA/AMSI WORKSHOP  
SYMMETRIES AND SPINORS  
INTERACTIONS BETWEEN GEOMETRY AND PHYSICS**

*The University of Adelaide, 13–17 April 2015*

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1. PROGRAM

**Lectures.**

- JOSE FIGUEROA-O’FARRILL (University of Edinburgh)
  1. *Supersymmetric supergravity backgrounds* (p. 3)  
Monday, 10:00 am.
  2. *Eleven-dimensional supergravity backgrounds* (p. 3)  
Tuesday, 10:00 am.
  3. *Gauge/gravity correspondence for M2 branes* (p. 4)  
Wednesday, 10:00 am.
  4. *The algebraic structure of three-dimensional superconformal field theories* (p. 4)  
Thursday, 10:00 am.
  5. *Some classification results for metric 3-algebras* (p. 4)  
Friday, 10:00 am.
- MAXIM ZABZINE (Uppsala University)  
*Localization techniques for supersymmetric gauge theories* (p. 5)  
daily, 1:30 pm.

**Talks.**

- DAVID BARAGLIA (The University of Adelaide)  
*A Fourier-Mukai approach to the K-theory of compact Lie groups* (p. 3)  
Wednesday, 3:30 pm.
- EVGENY BUCHBINDER (University of Western Australia)  
*Progress towards a realistic heterotic standard model* (p. 3)  
Wednesday, 2:30 pm.

- VLADIMIR CHERNOV (Dartmouth College)  
*Low conjecture, Linking and causality in globally hyperbolic Lorentz spacetimes* (p. 3)  
Thursday, 3:30 pm.
- SERGEI KUZENKO (University of Western Australia)  
*Supersymmetric Lorentzian Manifolds from Curved Superspace* (p. 4)  
Monday, 2:30 pm.
- PAUL NORBURY (University of Melbourne)  
*Topological recursion and Frobenius manifolds* (p. 4)  
Thursday, 2:30 pm.
- DAVID RIDOUT (Australian National University)  
*Two-dimensional superconformal algebras – still crazy after all these years* (p. 4)  
Friday, 2:30 pm.
- DENNIS THE (Australian National University)  
*Symmetry gaps for geometric structures* (p. 4)  
Monday, 3:30 pm.
- SIMON WOOD (Australian National University)  
*Two-dimensional conformal field theory with affine Lie algebra symmetry* (p. 5)  
Friday, 3:30 pm.

## 2. ABSTRACTS

**David Baraglia.** Wednesday, 3:00 pm.

*A Fourier-Mukai approach to the K-theory of compact Lie groups*

A famous problem in topology, first solved by Hodgkin in 1967, is to determine the K-theory of compact simply-connected Lie groups. Hodgkin's original proof was extremely technical, motivating the discovery of a number of simpler proofs. In this talk I will present a new, surprisingly simple proof of Hodgkin's theorem using the Fourier-Mukai transform in twisted K-theory. This talk is based on joint work with Pedram Hekmati.

**Evgeny Buchbinder.** Wednesday, 2:30 pm.

*Progress towards a realistic heterotic standard model*

I will discuss four-dimensional compactifications of the  $E_8 \times E_8$  heterotic string theory on a Calabi-Yau manifold with  $S(U(4) \times U(1))$  background gauge fields. Such models arise near the boundary of the stability cone where the vector bundle becomes polystable. In field theory the gauge group receives an additional  $U(1)$  factor which, under certain conditions, can combine with hypercharge to a global  $B - L$  symmetry (the difference between the baryon and lepton quantum numbers). I will present a specific model based on the monad construction, which leads to a supersymmetric standard model with three families of quarks and leptons, one pair of Higgs doublets, three right-handed neutrinos and no exotics charged under the standard model group. The presence of the  $B - L$  symmetry means that the model is safe from proton decay induced by dimension four operators. Due to the presence of a special locus in moduli space where the bundle structure group is Abelian and the low-energy symmetry enhances dimension five proton-decay inducing operators are also absent. In addition, this model possesses a certain Yukawa hierarchy which, in particular, leads to a large top quark mass.

**Vladimir Chernov.** Thursday, 3:00 pm.

*Low conjecture, Linking and causality in globally hyperbolic Lorentz spacetimes* (based on joint work with Stefan Nemirovski)

Low conjecture and the Legendrian Low conjecture formulated by Natário and Tod say that for many spacetimes  $X$  two events  $x, y$  in  $X$  are causally related if and only if the link of spheres  $S_x, S_y$  whose points are light rays passing through  $x$  and  $y$  is non-trivial in the contact manifold  $N$  of all light rays in  $X$ .

We prove the Low and the Legendrian Low conjectures and show that similar statements are in fact true in almost all 4-dimensional globally hyperbolic spacetimes.

We also show that on many 4-manifolds there is a unique smooth structure underlying a globally hyperbolic Lorentz metric. For instance, every contractible smooth 4-manifold admitting a globally hyperbolic Lorentz metric is diffeomorphic to the standard  $\mathbb{R}^4$ .

**José Figueroa-O'Farrill.** Monday–Friday, 10:00 am.

*1. Supersymmetric supergravity backgrounds*

A short historical introduction to supersymmetry and supergravity will be followed by the introduction of the main example: eleven-dimensional supergravity. We will define the notion of supersymmetric supergravity background and introduce the classification problem.

*2. Eleven-dimensional supergravity backgrounds*

We will go through some examples of supersymmetric supergravity backgrounds and discuss the state of the art in the classification problem. We will discuss the Killing superalgebra of a background, compute it in some examples and show and look at its properties under geometric limits.

### 3. *Gauge/gravity correspondence for M2 branes*

After a very brief discussion of the gauge/gravity correspondence, we will focus on the case of M2 branes: a conjectured correspondence between certain kinds of eleven-dimensional supersymmetric supergravity backgrounds and certain kinds of three-dimensional superconformal field theories. I will discuss in some detail some of the classification results on the gravity side.

### 4. *The algebraic structure of three-dimensional superconformal field theories*

Three-dimensional superconformal field theories dual to M2 branes have a rich algebraic structure, encoded in a Lie-like algebra defined by a ternary product. We will discuss the structure of these so-called 3-algebras and some of their properties.

### 5. *Some classification results for metric 3-algebras*

We discuss the relationship between metric 3-algebras and metric Lie algebras and state (and sketch the proofs) of several classification results.

**Sergei Kuzenko.** Monday, 2:30 pm.

### *Supersymmetric Lorentzian Manifolds from Curved Superspace*

This lecture will provide a pedagogical review of the formalism to determine supersymmetric backgrounds in off-shell supergravity theories, which was originally developed in 1995 in four spacetime dimensions. Alternative approaches to generate supersymmetric backgrounds have been advocated in the last four years. We will show how to read off the key results of these approaches from the formalism introduced twenty years ago.

**Paul Norbury.** Thursday, 2:30 pm.

### *Topological recursion and Frobenius manifolds*

I will describe a relationship between two powerful geometric tools in mathematical physics - topological recursion and Frobenius manifolds. Topological recursion is a procedure, originally arising out of matrix models, that computes a sequence of differentials on a plane curve. It gives a uniform description of a vast array of enumerative problems such as intersection numbers on the moduli space of curves, Gromov-Witten invariants, Hurwitz problems and knot invariants. A Frobenius manifold is essentially a family of 2-dimensional TQFTs. It is a manifold equipped with a Frobenius algebra structure - a product and a metric - on its tangent space at each point, which is encoded by a single potential that satisfies a nonlinear partial differential equation known as the Witten-Dijkgraaf-Verlinde-Verlinde (WDVV) equation. The talk will include a brief introduction to each of these topics.

**David Ridout.** Friday, 2:30 pm.

### *Two-dimensional superconformal algebras – still crazy after all these years*

The two-dimensional superconformal algebras predate the genesis of conformal field theory, first appearing in the dual resonance models that became superstring theory. These extended symmetries play fundamental roles in many applications of string theory to mathematics, for example in mirror symmetry, the AdS/CFT correspondence and Mathieu moonshine. Considering the enormous literature on these applications, our understanding of these superalgebras and their representation theories is surprisingly poor. This talk will review two-dimensional superconformal algebras, discuss some of the limits of our knowledge, and outline a broad framework whose aims include rectifying this state of affairs.

**Dennis The.** Monday, 3:30 pm.

### *Symmetry gaps for geometric structures*

For a given type of geometric structure, there is often a gap between the maximal and “sub-maximal” (infinitesimal) symmetry dimensions. This was first observed in the late 19th century

for Riemannian metrics and such symmetry gaps were subsequently classified for various other geometric structures on a case-by-case basis.

In recent work, Boris Kruglikov and I found a uniform approach to the symmetry gap problem for parabolic geometries, which is a diverse class of geometric structures that include conformal, projective, CR, 2nd order ODE systems, and large classes of generic distributions. A priori, submaximally symmetric structures need not even be homogeneous, but remarkably, in many cases this geometric problem reduces to Dynkin diagram combinatorics, and some submaximally symmetric models can be “immediately” found (in a sense that I will describe).

**Simon Wood.** Friday, 3:30 pm.

*Two-dimensional conformal field theory with affine Lie algebra symmetry*

String theories with Lie group target spaces define conformal field theories with affine Lie algebra symmetry. These theories constitute some of the first examples of conformal field theories ever considered. They are characterised by a parameter called the level and while non-negative integer levels are those which commonly appear in string theory, there are infinitely many other fractional levels which give rise to interesting conformal field theories that have received far less attention. This talk will give an overview of a wide reaching programme that aims to classify the representation theory of these fractional level affine Lie algebra conformal field theories, in the generality needed for physics applications.

**Maxim Zabzine.** Monday–Friday, 1:30 pm.

*Localization techniques for supersymmetric gauge theories*

In differential geometry, the Atiyah-Bott-Berline-Vergne localization formula states that the integral of an equivariant cohomology class on a manifold  $M$  with the torus action has only contributions from the fixed point set of the action. My main goal will be the discussion of the infinite dimensional version of this localization formula and its applications to the supersymmetric gauge theories on curved manifolds in different dimensions.

I will start by reviewing the Atiyah-Bott-Berline-Vergne theorem and reformulating it in the supergeometric language which is well-adapted to the infinite dimensional generalizations. As a first example, I will consider the Chern-Simons theory on three manifolds with  $U(1)$  action. Next I will review the 5D supersymmetric gauge theories on toric manifolds. If time allows I will briefly review the state of art in different dimensions, 2D, 3D, 4D, 5D, 6D and 7D.

## 3. SCHEDULE

	Monday	Tuesday	Wednesday	Thursday	Friday
10:00–11:45 am	Figuroa-O’Farrill	Figuroa-O’Farrill	Figuroa-O’Farrill	Figuroa-O’Farrill	Figuroa-O’Farrill
break					
1:30–2:15 pm	Zabzine	Zabzine	Zabzine	Zabzine	Zabzine
2:30–3:15 pm	Kuzenko	<i>WIMSIG gathering</i> 3:00 pm	Buchbinder	Norbury	Ridout
3:30–4:15 pm	The		Baraglia	Chernov	Wood

The first lecture on Wednesday, 10:00 am, will be in Seminar Room B21 in the basement of the Ingkarni Wardli Building at The University of Adelaide. All other talks will be in Conference Room 7.15 on Level 7 of the Ingkarni Wardli Building.

### 4. FOOD OPTIONS

The most popular dining areas are *Rundle Street* near the university; *O'Connell Street* and *Melbourne Street* in North Adelaide; *Gouger Street* in the city centre, which is Adelaide's "China Town"; and at lunch time there are several food courts available along *Rundle Mall*.



## 5. REGISTERED PARTICIPANTS

- (1) David Baraglia (The University of Adelaide), Speaker
- (2) Dmitry Berdinski (University of Auckland)
- (3) Peter Bouwknegt (Australian National University), Organiser
- (4) Nicholas Buchdahl (The University of Adelaide)
- (5) Mark Bugden (Australian National University)
- (6) Evgeny Buchbinder (University of Western Australia), Speaker
- (7) Joseph Chan (University of Melbourne)
- (8) Vladimir Chernov (Dartmouth College), Speaker
- (9) Michael Cromer (Australian National University)
- (10) Sean Curry (University of Auckland)
- (11) Wolfgang Globke (The University of Adelaide), Organiser
- (12) José Figueroa-O'Farrill (University of Edinburgh), Speaker
- (13) Pedram Hekmati (The University of Adelaide), Organiser
- (14) Peter Hochs (The University of Adelaide)
- (15) Masoud Kamgarpour (University of Queensland)
- (16) Sergei Kuzenko (University of Western Australia), Speaker
- (17) Finnur Larusson (The University of Adelaide)
- (18) Thomas Leistner (The University of Adelaide), Organiser
- (19) Andree Lischewski (The University of Adelaide)
- (20) Colin Mitchell (The University of Adelaide)
- (21) Benedict Morrissey (Australian National University)
- (22) Paul Norbury (University of Melbourne), Speaker
- (23) Joseph Novak (University of Western Australia)
- (24) Jeremy Nugent (University of New South Wales)
- (25) David Ridout (Australian National University), Speaker
- (26) Steve Siu (Australian National University)
- (27) Igor Samsonov (University of Western Australia)
- (28) Vincent Schlegel (ETH Zürich)
- (29) Danny Stevenson (The University of Adelaide)
- (30) Dennis The (Australian National University), Speaker
- (31) Guo Chuan Thiang (The University of Adelaide)
- (32) Mathai Varghese (The University of Adelaide)
- (33) Raymond Vozzo (The University of Adelaide)
- (34) Hang Wang (The University of Adelaide)
- (35) Simon Williams (Flinders University)
- (36) Simon Wood (Australian National University), Speaker
- (37) Maxim Zabzine (Uppsala University), Speaker

## 6. WORKSHOP DINNER

The workshop dinner will be at the *Red Ochre Grill* on War Memorial Drive in North Adelaide (see the map on p. 7), on Tuesday, April 14, at 7:30 pm. Participants are invited to join the organisers outside the Ingkarni Wardli Building at 7:00 pm to walk to the restaurant.

Please notify the organisers if you wish to attend the dinner.