Parameterized Morse Theory in Low-Dimensional and Symplectic Topology
March 23- March 28, 2014

MEALS

*Breakfast (Buffet): 7:00–9:30 am, Sally Borden Building, Monday–Friday
*Lunch (Buffet): 11:30 am–1:30 pm, Sally Borden Building, Monday–Friday
*Dinner (Buffet): 5:30–7:30 pm, Sally Borden Building, Sunday–Thursday
Coffee Breaks: As per daily schedule, in the foyer of the TransCanada Pipeline Pavilion (TCPL)
***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

MEETING ROOMS

All lectures will be held in the lecture theater in the TransCanada Pipelines Pavilion (TCPL). An LCD projector, a laptop, a document camera, and blackboards are available for presentations.

SCHEDULE

Sunday

16:00	Check-in begins (Front Desk - Professional Development Centre - open 24 hours)
17:30–19:30	Buffet Dinner, Sally Borden Building
20:00	Informal gathering in 2nd floor lounge, Corbett Hall (if desired) Beverages and a small assortment of snacks are available on a cash honor system.

Monday

7:00–8:45	Breakfast
8:45–9:00	Introduction and Welcome by BIRS Station Manager, TCPL
9:00–10:00	*Parametrised Morse theory for 3-manifolds* (Rubinstein)
10:00–10:30	Coffee Break, TCPL
10:30–11:30	*Singular Fibrations on 4-Manifolds* (Behrens)
11:30–13:00	Lunch
13:00–14:00	Guided Tour of The Banff Centre; meet in the 2nd floor lounge, Corbett Hall
14:00–15:00	*From the cobordism hypothesis to higher Morse theory* (Schommer-Pries)
15:00–15:30	Coffee Break, TCPL
15:30–16:30	*An Introduction to Symplectic and Contact Topology and the Technique of Generating Families* (Traynor)
17:30–19:30	Dinner

Tuesday

7:00–9:00	Breakfast
9:00–10:00	*Minsky Models and Morse two-functions on three-manifolds* (Johnson)
10:00–10:30	Coffee Break, TCPL
10:30–11:30	*Knots with compressible thin levels* (Zupan)
11:30–13:30	Lunch
13:30–14:30	*The Schönflies Conjecture and its spin-offs* (Scharlemann)
14:30–15:00	Coffee Break, TCPL
15:00–16:00	*Weak Floer A-infinity algebras for smooth 4-manifolds* (Williams)
16:15–17:15	*How to extend 2+1 (symplectic but not quite) field theories to 2+1+1* (Wehrheim)
17:30–19:30	Dinner
19:30–	Problem Session in 3- and 4-dimensional topology (Kirby and Thompson)

Wednesday

7:00–9:00	Breakfast
9:00–10:00	*Computations with topological defects* (Vicary)
10:00–10:30	Coffee Break, TCPL
10:30–11:30	*Three-dimensional bordism representations via generators and relations* (Bartlett)
11:30–13:30	Lunch
	Free Afternoon
17:30–19:30	Dinner
19:30–	Problem Session in quantum field theory (Melvin and Teichner)

Thursday

7:00–9:00	Breakfast
9:00–10:00	*Families of Legendrian Submanifolds via Generating Families* (Sabloff)
10:00–10:30	Coffee Break, TCPL
10:30–11:30	*All manifolds are contact except those which are obviously not* (Eliashberg)
11:30–13:30	Lunch
13:30–14:30	*A combinatorial differential graded algebra for Legendrian knots from generating families* (Henry)
14:30–15:00	Coffee Break, TCPL
15:00–15:30	Group Photo; meet in foyer of TCPL (photograph will be taken outdoors so a jacket might be required).
15:30–16:30	*Cellular computation of Legendrian contact homology and generating families* (Rutherford)
17:30–19:30	Dinner
19:30–	Problem Session in symplectic and contact geometry (Bourgeois)

Friday

7:00–9:00	Breakfast
9:00–10:00	*Triangulating 4-manifolds and a table of knots in homotopy 4-spheres* (Budney)
10:00–10:30	Coffee Break, TCPL
10:30–11:30	TBD
11:30–13:30	Lunch

Checkout by 12 noon.

** 5-day workshop participants are welcome to use BIRS facilities (BIRS Coffee Lounge, TCPL and Reading Room) until 3 pm on Friday, although participants are still required to checkout of the guest rooms by 12 noon. **

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ABSTRACTS
(in alphabetic order by speaker surname)

Speaker: **Bruce Bartlett**
Title: *Three-dimensional bordism representations via generators and relations*
Abstract: The three-dimensional oriented bordism bicategory has closed 1-manifolds as objects, 2-dimensional cobordisms as 1-morphisms, and diffeomorphism classes of 3-dimensional cobordisms as 2-morphisms. We use higher Morse theory to find a simple generators-and-relations presentation of it. Dropping a certain relation leads to a "signature" central extension of the oriented bordism bicategory. The presentation allows for an elementary proof that a representation of this bicategory (i.e. a "123 TQFT") corresponds in a 2-1 fashion to a modular category, which must be anomaly-free in the oriented case. J/w Chris Douglas, Chris Schommer-Pries, Jamie Vicary.

Speaker: **Stefan Behrens**
Title: *Singular Fibrations on 4-Manifolds*
Abstract: The last 15 years of 4-manifold theory have seen a revival of the study of smooth maps to surfaces. While this subject had already enjoyed popularity in the third quarter of the 20th century, the current developments were motivated by work of Donaldson and Gompf on symplectic 4-manifolds and Lefschetz pencils as well as Taubes's work on the Seiberg-Witten invariants of near-symplectic 4-manifolds. In this talk I will begin with a brief historical overview and then go on to describe the basic structure of generic maps from 4-manifolds to surfaces and 1-parameter families thereof. I will point out relations to 3- and 4-dimensional Morse theory and the theory of (broken) Lefschetz fibrations. Finally, I will describe how this "surface valued Morse theory" leads to pictorial descriptions of 4-manifolds in terms of curve configurations on surfaces. If time permits, I will discuss some (potential) applications and open problems.

Speaker: **Ryan Budney**
Title: *Triangulating 4-manifolds and a table of knots in homotopy 4-spheres.*
Abstract: I will update the group on an ongoing project which creates a census of triangulated smooth 4-manifolds. The ultimate goal of the project is to see how computationally useful triangulations of 4-manifolds can be, as compared to with 3-manifold theory. The table of knot exteriors in homotopy 4-spheres is nearing completion, this has included the discovery of a new 2-knot type.

Speaker: **Yasha Eliashberg**
Title: *All manifolds are contact except those which are obviously not.*

Speaker: **M. Brad Henry**
Title: *A combinatorial differential graded algebra for Legendrian knots from generating families*
Abstract: We outline recent work that assigns a differential graded algebra (DGA) to a Legendrian knot in the standard contact structure on $\mathbb{R}^3$. The definition of the DGA is motivated by considering Morse-theoretic data from a generating family. A generating family f_x for a Legendrian knot is a 1-parameter family of functions whose Cerf diagram is a projection of the knot. Generating family homology is a useful invariant of Legendrian knots extracted from the generating family. The new DGA is defined combinatorially using the Cerf diagram and handleslide data from f_x. Although defined combinatorially, the differential of the DGA is geometrically motivated by a conjectured extension of generating family

homology using gradient flow trees. We will discuss this motivation and how it informs the combinatorial definition of the DGA, and relate the new DGA to the Chekanov-Eliashberg DGA. This work is joint with Dan Rutherford (University of Arkansas).

Speaker: **Jesse Johnson**
Title: *Minsky Models and Morse two-functions on three-manifolds*
Abstract: Morse two-functions have recently become popular in three-dimensional topology via the closely related of a (Rubinstein-Scharlemann) graphic. In this talk, I will describe how a Morse two-function on a three-dimensional manifold encodes topological and geometric information about the three-manifold via a combinatorial structure called a Minsky model.

Speaker: **Daniel Rutherford**
Title: *Cellular computation of Legendrian contact homology and generating families*
Abstract: This is joint work with Mike Sullivan. We consider a Legendrian surface, L, in $\mathbb{R}^5$ (or more generally in the 1-jet space of a surface). Such a Legendrian, L, can be conveniently presented via its front projection which is a surface in $\mathbb{R}^3$ that is immersed except for certain standard singularities.

We associate a differential graded algebra (DGA) to L by starting with a cellular decomposition of the base projection (to $\mathbb{R}^2$) of L that contains the projection of the singular set of L in its 1-skeleton. A collection of generators is associated to each cell, and the differential is determined in a formulaic manner by the nature of the singular set above the boundary of a cell. Our motivation is to give a cellular computation of the Legendrian contact homology DGA of L. In this setting, the construction of Legendrian contact homology was carried out by Etnyre-Ekholm-Sullvan with the differential defined by counting holomorphic disks in $\mathbb{C}^2$ with boundary on the Lagrangian projection of L. In work in progress, we hope to establish equivalence of our DGA with LCH using work of Ekholm on gradient flow trees.

As an application we discuss connections between the cellular DGA and generating families. Here, augmentations arise from Morse complexes and bifurcation data appearing in 2-parameter families of functions.

Speaker: **Hyam Rubinstein**
Title: *Parametrised Morse theory for 3-manifolds*
Abstract: The first part of the talk will be a quick survey on the homotopy type of the group of Diffeomorphisms of a 3-manifold. Pioneering work was done by Hatcher and Ivanov in the late 70s and early 80s, computing this for Haken 3-manifolds and famously the Smale conjecture. Following Thurston, the natural question is whether Diff is homotopy equivalent to the group of isometries, for geometric 3-manifolds. Gabai showed this is true in the hyperbolic case. McCullough and others studied Seifert fibred spaces and many spherical classes of examples.

In the second part, I will talk about Heegaard splittings, a natural view of Morse theory for 3-manifolds. Casson-Gordon in the mid 1980s introduced a key idea of strong irreducibility and this was extended by Scharlemann-Thompson to telescoping. There have subsequently been many developments, including classification of splittings for all 7 non hyperbolic geometries of Thurston. Comparing splittings was introduced by Scharlemann and I, and distance of splittings by Hempel. If time permits the relationship with hyperbolic geometry will be sketched.

Speaker: **Josh Sabloff**
Title: *Families of Legendrian Submanifolds via Generating Families*
Abstract: I will introduce a framework to investigate families of Legendrian submanifolds using generating family homology through an application of the families theory to the analysis of a loop of Legendrian n-spheres in the standard contact space that is contractible in the smooth, but not Legendrian, category; this is joint work with Mike Sullivan. The computation of generating family homology necessary for the application comes from joint work with on Lagrangian cobordisms withFrederic Bourgeois and Lisa Traynor.

Speaker: **Martin Scharlemann**
Title: *The Schönflies Conjecture and its spin-offs*
Abstract: We briefly review the resolution of the Schnflies Conjecture in all dimensions other than four, discuss why the remaining conjecture is important, and the classic approach to its resolution. This approach has spawned much beautifully pictorial mathematics, without actually succeeding. An underlying theme is that, although the conjecture has not yet been settled, it interlocks with and has inspired much interesting topology in dimensions three and four.

Speaker: **Chris Schommer-Pries**
Title: *From the cobordism hypothesis to higher Morse theory*
Abstract: This talk will survey some recent developments in our understanding of extended topological field theories and their classification. This includes the cobordism hypothesis and related results. In the course of this talk we hope to make clear the role of higher Morse theory in this story.

Speaker: **Lisa Traynor**
Title: *An Introduction to Symplectic and Contact Topology and the Technique of Generating Families*
Abstract: I will give a brief introduction to some of the major objects in symplectic and contact topology: symplect and contact manifolds, Lagrangian and Legendrian submanifolds, and symplectic and contact diffeomorphisms. Then I will describe the technique of generating families: this is a way to encode a Lagrangian or Legendrian submanifold by a parameterized family of functions. Morse-theoretic constructions then lead to generating family (co)homology groups for a Legendrian submanifold and wrapped generating family (co)homology groups for a Lagrangian cobordism. I will also describe how from a Lagrangian cobordism with a generating family, one obtains a cobordism map that satisfies some of the typical properties of a TQFT.

Speaker: **Jamie Vicary**
Title: *Computations with topological defects*
Abstract: I will show how some fundamental computational processes, including encrypted communication and quantum teleportation, can be defined in terms of the higher representation theory of defects between 2d topological cobordisms, giving insight into fundamental questions in classical and quantum computation. No knowledge of computer science will be required to understand this talk.

Speaker: **Katrin Wehrheim**
Title: *How to extend 2+1 (symplectic but not quite) field theories to 2+1+1*
Abstract: In previous work with Chris Woodward, we gave constructions of 2+1 NQFT's (not quite field theories) via dimensionally reduced gauge theories and the symplectic 2-category. More precisely, these are functors from the category of connected 2+1 bordisms to Symp, composed with a natural functor from Symp to Cat. Using Morse 2-functions on 4-manifolds, I will explain that/how such theories naturally extend to 2+1+1 NQFT's under a single nontrivial axiom. And I hope to find help for translating this into the more algebraic TFT language during the workshop.

Speaker: **Jonathan Williams**
Title: *Weak Floer A-infinity algebras for smooth 4-manifolds*
Abstract: I will talk about how to apply constructions of Lipshitz and Akaho-Joyce to a certain class of maps from 4-manifolds to the 2-sphere to yield possibly new diffeomorphism invariants for general smooth, closed oriented 4-manifolds, and discuss future directions.

Speaker: **Alexander Zupan**
Title: *Knots with compressible thin levels*
Abstract:Thin positions theories have played a prominent role in 3-manifold topology over the last several decades, beginning with Gabai's definition of thin position for knots in the 3-sphere and proceeding up to

Johnson's axiomatic thin position, which encompasses most existing adaptations. Modern notions of thin position are highly technical but exhibit the natural property that for a thin presentation of a knot or a 3-manifold, all thin surfaces are essential. This motivates the question, "For a knot in Gabai thin position, are all thin levels essential in the knot exterior?" We give a negative answer to this question, exhibiting an infinite family of knots whose thin positions have compressible thin levels. This is joint work Ryan Blair.