Research Networking Programmes

Science Meeting – Scientific Report

Proposal Title: Workshop on Symplectic Geometry, Contact Geometry and Interactions

Application Reference N°: 4681

1) Summary

The VIII Workshop on Symplectic Geometry, Contact Geometry, and Interactions (http://cast.math.ist.utl.pt/) was the 8th in a series of conferences on symplectic geometry and contact geometry. The conference is intended to bring together young researchers in the areas of symplectic and contact geometries to discuss their work in a relaxed atmosphere and hear about the latest developments that took place in the area over the last year.

The workshop was extremely well attended (we had over 120 participants). In fact this edition of the Workshop was the one with most participants. The conference room was always packed with mathematicians eager to hear of each other works. There were 12 talks on many different areas of contact/symplectic geometry ranging from knot theory to Kahler geometry. This made for a broad range symplectic/contact geometry conference in which people were often listening to mathematics outside their usual scope. Speakers were all very careful to take this into account and prepared talks that were largely accessible while still conveying interesting new results.

This year we received 42 PhD students and 25 young postdocs in Lisbon. The presence of many young mathematicians made for a very informal atmosphere fostering discussion and interactions between different areas of symplectic and contact geometry. Of the 12 speakers, 5 were postdocs or PhD students. The average quality of the work these young mathematicians presented is quite outstanding and it is very satisfying to see that the area remains in very goods hands. It is also a important sign of vitally as well as a promise of great developments for the future.

To summarize, on a more technical level we saw different sorts of results being presented:

1) Those that were surprising and that give us a sense of work to be done (existence results for complicated abundant Lagrangians as those of Emmy Murphy, unexpected intricate connections between symplectic and symplectic geometry as studied by Sylvain Courte)
2) Those results that are closure results and which build on previous work and settle a question that has been looked at before (John Pardon's work for example may at last give a satisfying definition of Floer Homology, Milena Pabiniak´s view of toric manifolds which gives another way to understand their Lagrangians or Paul Biran's very computable Floer type invariants of Lagrangian spheres)
3) In some other talks we saw symplectic techniques applied to other areas. Such was the case of Ana Lecuona's work where one applies Floer Theory to study knots, or of Dietmar Salamon´s work on Geometric Invariant Theory. Other examples were Leonardo Macarini's and Claude Viterbo's talks where a dynamical system's question was addressed using symplectic techniques. This sort of application is very close to the history of the subject of symplectic geometry and goes back to Arnold.

This shows that symplectic/contact geometry is very much an open, alive area where real progress is being made and whose impact on mathematics is profound and broad.

2) Description of the scientific content of and discussions at the event

There were talks in essentially the entire spectrum of the area of symplectic/contact geometry. Raging from talks on the foundations of the subject to talks with applications to knot theory.

Foundational talks: Even though symplectic geometry has been much studied in the past 20/30 years much of the foundation of the subject remains to be cleaned up. In particular there has been great effort devoted to defining some Floer Homology type theories that would serve as invariants. Many analytic difficulties arise and it has become clear over the years that one needs a breakthrough to deal with the most general situations. In his talk, John Pardon proposed a very general method to deal with the so-called "moduli" problems that may well be applicable in Floer Theory or Gromov theory as well as in other related instances. The classical way to construct Floer Homology is to think of it at the Morse Theory of a certain infinite dimensional functional. This idea has been very fruitful in geometry but in the special case of symplectic geometry it has not yet been possible to resolve technical issues that prevent one from defining Floer Homology this way in as much generality as one would need it to be.
In his talk, Alexandru Oancea described a Morse Theory on loop spaces of manifolds that does yield interesting results. In some cases Alexandru explained how to use such a theory to calculate the homology of Loops spaces.

Dietmar Salamon gave another foundational talk and explained finite dimensional Geometric Invariant Theory from a different purely differential-geometric perspective. This builds on work of Chen-Donaldson-Sun for a specific infinite-dimensional GIT problem related to the Kahler-Einstein problem that was recently settled.

Applications of Floer Theory: In the opposite end of the spectrum, Ana Lecuona spoke about slice knots. Using Floer homology in a context where it is well defined as shown by Ozsváth and Szabó as well as more classical knot theory, she attacked the question "when is a pretzel knot of slice type?" She has not fully answered this question yet but made some interesting progress by finding a necessary numerical condition. Many in the audience were not experts but Ana gave a beautiful talk and managed to give all the needed background and still describe some the new ideas involved in her work.

Leonardo Macarini also explained how he could make use of Floer Theory in a context where it is fully well defined to deduce existence of certain type of periodic orbits of the so called Reeb flow in some cases of interest.

There is a natural connection between contact and symplectic geometry. This is a method to produce symplectic manifolds out of contact manifolds called symplectization. It is then natural to ask: if two contact manifolds have isomorphic symplectizations are they the same? In his talk Sylvain Courte discussed this question and explained how to construct two non-diffeomorphic contact manifolds with the same symplectization which is perhaps somewhat surprising.

Lagrangians submanifolds: Emmy Murphy described a method to obtain some Lagrangian submanifolds in Euclidean space that are different from all the Lagrangians that were previously constructed thus showing how complicated a general theory of Lagrangian Floer Homology can actually be.
Finding Lagrangians inside symplectic manfolds is an important way to understand and study a symplectic structure. While Emmy Murphy's talk indicated how flabby the Lagrangian condition can be in Euclidean space, the general idea is that in compact symplectic manifolds Lagrangian submanifolds are a lot more rigid and there are obstructions to their existence and intersection theory. Paul Biran described how to construct some concrete invariants of Lagrangian spheres in symplectic manifolds and explained how might proceed to calculate them. Matthew Strom Borman also described some rigidity phenomenon for Lagrangian spheres which he discovered by studying a symplectic ball packing problem. Frol Zapolsky described yet another rigidity type phenomenon taking place on contact manifolds of certain type (line bundles over symplectic toric manifolds). He uses the tool of quasi-morphism of groups to read off this sort of rigidity. Also in the context of Toric Geometry, Milena Pabiniak explained how to give an alternative construction of toric manifolds as quotients of Cartesian products of weighted projective spaces and used this fact to find non-displaceable Lagrangians inside toric manifolds. This result was previously known, but this new construction sheds a new light into the question and may prove to have other applications.

3) Assessment of the results and impact of the event on the future directions of the field

On a practical level, the conference was a very big success. We had outstanding talks presenting very strong results to an interested audience. The speakers did a terrific job at presenting the results in an accessible ways so as to keep a dialogue between different subareas of symplectic geometry and contact geometry.

There also seems to have been a great deal of mathematical interaction. A couple speakers like Matthew Strom Borman, Leonardo Macarini were in Lisbon prior to the workshop to collaborate with local mathematicians. Some participants also took the opportunity to work on joint projects. For example Rémi Leclercq, Sonia Hohloch, Tony Rieser, Sheila Sandon, just to mention a few names, stayed on after the workshop and were able to progress on their mathematical work.

During the conference there was also quite a lot of mathematical discussion over tea and over lunch. Young researchers had the opportunity to meet and ask question and work together over breaks in the conference room lounge.

As far as concrete mathematical influence, it seems worth mentioning that John Pardon's result and the ideas behind it, if true, will have an enormous impact on the future of symplectic geometry. In fact a lot of effort has been put on developing a technique that will allow one to define Gromov-Witten invariants or Hamiltonian Floer homology in a general setting without having to deal with transversality issues that often restrict the scope of the theorems in the area. Pardon seems to have a found an elegant simple solution to this problem. Also, it would seem that one may be able to apply Pardon's techniques to other Floer type problems including the systematic study of Lagrangians.

In the opposite direction there is a lot of rigidity in the symplectic category and geometers are still discovering obstructions to the existence of Lagrangians. In Paul Biran's work it is pleasantly surprising to see that some of these obstructions are becoming less mysterious and we are on a path to explicit calculations.

On the one hand it was obvious from this conference that there is still a lot about symplectic manifolds and contact manifolds that we don't know. The objects we are studying are complicated and carry a lot of structure far beyond what we can keep track of.

On the other hand there seems to be real progress. We now have concrete ways to extract information out of Floer Homology in its numerous flavours. This information seems to be far-reaching and deep and one can see how it will impact Knot Theory, the Theory of Dynamical Systems, Algebraic Geometry as well as Symplectic and Contact Geometry.

4) Annexes 4a) and 4b): Programme of the meeting and full list of speakers and participants

Annex 4a: Programme of the meeting

Thursday, January 30

10:00 - 12:00	Registration
12:00 - 13:30	Lunch Break
13:30 - 14:30	**Leonardo Macarini**
14:45 - 15:45	**Milena Pabiniak**
15:45 - 16:15	Coffee Break
16:15 - 17:15	**Ana Lecuona**
17:30 - 18:30	**Sylvain Courte**

Friday, January 31

09:30 - 10:30	**Paul Biran**
10:30 - 11:00	Coffee Break
11:00 - 12:00	**John Pardon**
12:00 - 14:00	Lunch Break
14:00 - 15:00	**Matthew Strom Borman**
15:15 - 16:15	**Emmy Murphy**
16:15 - 16:45	Coffee Break
16:45 - 17:45	**Dietmar Salamon**

Saturday, February 1

09:00 - 10:00	**Alexandru Oancea**
10:00 - 10:30	Coffee Break
10:30 - 11:30	**Claude Viterbo**
11:45 - 12:45	**Frol Zapolsky**

Abstracts

Paul Biran : The Lagrangian cubic equation

We will discuss calculation of new and older invariants associated to the Floer homology of Lagrangian spheres and other manifolds. We will also explain the relation of these invariants with the ambient quantum homology, and in particular how they can be extracted from a cubic equation associated to the Lagrangian submanifolds. Finally, we will discuss how these invariants behave under Lagrangian cobordisms. Joint work with Cedric Membrez.

Matthew Strom Borman : Spherical Lagrangians via ball packings and symplectic cutting

In this talk I will present a proof of the connectedness of symplectic ball packings in the complement of a spherical Lagrangian, S^2 or RP^2, in symplectic manifolds that are rational or ruled. I will then explain some of the applications of this result such as: unknottedness results for spherical Lagrangians, the transitivity of the action of the symplectic Torelli group, and classifying Lagrangian isotopy classes in the presence of knotting. This is joint work with Tian-Jun Li and Weiwei Wu.

Sylvain Courte: h-cobordisms and flexible Weinstein structures

We will discuss how to construct non-diffeomorphic high-dimensional contact manifolds with isomorphic symplectizations. This will make use of the s-cobordism theorem as well as Cieliebak and Eliashberg's results on flexibility of Weinstein structures. Then we will explain that these non-diffeomorphic contact manifolds become in fact contactomorphic after some stabilization process that we will describe.

Ana Lecuona: Slice pretzel knots: Casson-Gordon invariants vs. Heegaard-Floer correction terms

In this talk we will discuss when do pretzel knots in the three sphere bound embedded discs in the four ball. Such pretzel knots are called slice and their double branched covers are the boundary of rational homology balls. In order to determine which of these three manifolds bound rational homology balls we shall use the Casson-Gordon invariants as well as the d-invariants from Heegaard-Floer homology.

Leonardo Macarini: Dynamical convexity and elliptic orbits for Reeb flows

A classical conjecture in Hamiltonian Dynamics states that the Reeb flow of any convex hypersurface in even-dimensional Euclidean space carries an elliptic closed orbit. Dell'Antonio-D'Onofrio-Ekeland proved it in 1995 for antipodal invariant convex hypersurfaces. In this talk I will present a generalization of this result using contact homology and a notion of dynamical convexity first introduced by Hofer-Wysocki-Zehnder for tight contact forms on the 3-sphere. Applications include geodesic flows under pinching conditions, magnetic flows and toric contact manifolds. This is joint work with Miguel Abreu.

Emmy Murphy: Exotic Lagrangians in C^n

Using the methods of Lagrangian caps, we construct new examples of Lagrangian embeddings and immersions in symplectic C^n. For instance, we construct Lagrangians of Maslov class zero of any 3-manifold of the form $(S^1 \times S^2) \# M$. These examples have infinite relative Gromov width, and do not admit a uniruling by holomorphic disks. We discuss the construction of such Lagrangians, and demonstrate their properties. As time allows we discuss exotica in other symplectic manifolds, in particular exact Lagrangian embeddings in symplectizations.

Alexandru Oancea: Completing manifolds in Morse theory

I will explain through examples the notion of a completing manifold, a geometric tool for detecting perfect Morse functions which goes back to the work of Morse and Bott-Samelson. This notion has remarkable applications to the computation of the homology of loop and path spaces on manifolds that admit large groups of symmetries. The talk is based on joint work with Nancy Hingston.

Milena Pabiniak: Symplectic toric manifolds as centered reductions of products of weighted projective spaces

We prove that every symplectic toric orbifold is a "centered" symplectic reduction of a Cartesian product of weighted projective spaces. Reduction is centered if the level set contains central Lagrangian torus fiber of the product of weighted projective spaces. In that case one can deduce certain information about non-displaceable sets or existence of quasimorphisms. For example, a theorem of Abreu and Macarini shows that if the level set of the reduction passes through a non-displaceable set then the image of this set in the reduced space is also non-displaceable. Using this theorem and our result we reprove that every symplectic toric orbifold contains a non-displaceable fiber and identify this fiber. Joint work with Aleksandra Marinkovic.

John Pardon: Implicit atlases and virtual fundamental cycles

An implicit atlas on a (moduli) space consists of certain auxiliary (moduli) spaces satisfying a precise set of axioms. We will summarize the construction of implicit atlases on moduli spaces of J-holomorphic curves, under the assumption of a precise "strong gluing" theorem (one which we expect to follow from standard techniques). We will also describe an algebraic "theory of virtual fundamental cycles" (which does not use perturbation) in the abstract setting of spaces equipped with implicit atlases. This "VFC package" is sufficient to define Floer-type homology theories from a collection of (moduli) spaces equipped with a compatible system of implicit atlases.

Dietmar Salamon: GIT and the moment-weight inequality

In this lecture I will explain the moment-weight inequality, and its role in the proof of the Hilbert-Mumford numerical criterion for μ-stability. The setting is Hamiltonian group actions on closed Kaehler manifolds. The moment-weight inequality relates the Mumford numerical invariants to the norm of the moment map on the complexified group orbit. Key ingredients in the proof are the negative gradient flow of the moment map squared and the Kemp-Ness function. This is joint work with Valentina Georgoulas and Joel Robbin, based on conversations with Xiuxiong Chen, Song Sun, and Sean Paul.

Frol Zapolsky: Contact rigidity and quasi-morphisms on contactomorphism groups

I will outline the construction of homogeneous quasi-morphisms on contactomorphism groups of prequantization spaces over certain monotone toric symplectic manifolds and show how they can be used to detect a hierarchy of rigid subsets in these contact manifolds. Time pernitting, I will describe other applications of these quasi-morphisms as well as how to enlarge the class of symplectic manifolds admitting a prequantization space whose contactomorphism group carries a homogeneous quasi-morphism. Based on joint work with M. Strom Borman.

Annex 4b: Full list of speakers and participants

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