CIRM, Luminy, June 2016.

Analysis, Geometry and Topology of Stratified Spaces

Pierre Albin (University of Illinois at Urbana-Champain)

Extending the Cheeger-Müller theorem through degeneration

Abstract: Reidemeister torsion was the first topological invariant that could distinguish between spaces which were homotopy equivalent but not homeomorphic. The Cheeger-Mller theorem established that the Reidemeister torsion of a closed manifold can be computed analytically. I will report on joint work with Frdric Rochon and David Sher on finding a topological expression for the analytic torsion of a manifold with fibered cusp ends. Examples of these manifolds include most locally symmetric spaces of rank one. We establish our theorem by controlling the behavior of analytic torsion as a space degenerates to form hyperbolic cusp ends .

WITTEN'S PERTURBATION ON STRATA WITH GENERAL ADAPTED METRICS

JESÚS A. ÁLVAREZ LÓPEZ

Abstract. Let M be a stratum of a compact stratified space A. It is equipped with a general adapted metric g, which is slightly more general than the adapted metrics of Nagase and Brasselet-Hector-Saralegi. In particular, g has a general type, which is an extension of the type of an adapted metric. A restriction on this general type is assumed, and then g is called good. We consider the maximum/minimun ideal boundary condition, $d_{\mathrm{max/min}}$, of the compactly supported de Rham complex on M, in the sense of Brüning-Lesch, defining the cohomology $H^*_{\mathrm{max/min}}(M)$, and with corresponding Laplacian $\Delta_{\mathrm{max/min}}$. The first main theorem states that $\Delta_{\mathrm{max/min}}$ has a discrete spectrum satisfying a weak form of the Weyl's asymptotic formula. The second main theorem is a version of Morse inequalities using $H^*_{\mathrm{max/min}}(M)$ and what we call rel-Morse functions. The proofs of both theorems involve a version for $d_{\mathrm{max/min}}$ of the Witten's perturbation of the de Rham complex, as well as certain perturbation of the Dunkl harmonic oscillator previously studied by the authors using classical perturbation theory. The condition on g to be good is general enough in the following sense: using intersection homology when A is a stratified pseudomanifold, for any perversity $\bar{p} \le \bar{m}$, there is an associated good adapted metric on M satisfying the Nagase isomorphism $H^r_{\mathrm{max}}(M) \cong I^{\bar{p}}H_r(A)^*$ ($r \in \mathbb{N}$). If M is oriented and $\bar{p} \ge \bar{n}$, we also get $H^r_{\mathrm{min}}(M) \cong I^{\bar{p}}H_r(A)$. Thus our version of the Morse inequalities can be described in terms of $I^{\bar{p}}H_*(A)$.

This work is in collaboration with Manuel Calaza and Carlos Franco.

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Regularity of eigenfunctions of the Schrödinger equation

joint work with V. Nistor

Abstract: Let $H = \Delta + V$ be the classical Schrödinger operator for a system of N particles, i.e. Δ is the Laplacian acting on functions on R^{3N} and V is a $1/r$-type potential which is singular if and only if at least two of the particles meet. We study regularity properties for eigenfunctions of H. As the potential is assumed to be smooth outside the singular set, all eigenfunctions are smooth as long as all particles remain separated. However, when at least two particle meet, eigenfunctions are no longer smooth.

On the other hand, we will see that if one expresses the eigenfunction in suitable polar coordinates, it is still smooth, with all derivative uniformly bounded. If two particles meet, then standard polar coordinates are these "suitable polar coordinates", but the main focus of the presented research deals with those singular points where at least three particles meet. Our approach is to blow-up the singular set. Then the conformally related operator has a smooth potential with all derivatives bounded. This blowing-up construction is not only used to proof the statement, but also to provide a recipe to iteratively construct this kind of polar coordinates.

As the main technique is to use Lie algebras of vector fields to express the geometry of the blown-up space (similar to Melrose's b-calculus), we will also shortly sketch such techniques. These techniques are closely related to the analysis of stratified spaces.

In recent work we combine the previous blowup procedures with the Kustaanheimo-Stiefel transform which provides much stronger regularity statements for two-particle collissions in 3-dimensional space.

THE YAMABE FLOW OF AN INCOMPLETE EDGE METRIC

ERIC BAHUAUD

The normalized Yamabe flow is a geometric evolution equation that evolves a metric toward one of constant scalar curvature. In this talk I describe recent work to understand the behaviour of this flow in a singular setting modeled by an incomplete edge metric. I will discuss the background estimates obtained from an appropriate heat kernel, conditions for short-time existence and our recent work obtaining long-time existence and convergence when the initial metric has negative scalar curvature. This is ongoing work with Boris Vertman.

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Markus Banagl, Universität Heidelberg.

Title:
The L-Homology Fundamental Class for Singular Spaces and the stratified Novikov Conjecture

Abstract:
An oriented manifold possesses an L-homology fundamental class which is an integral refinement of its Hirzebruch L-class and assembles to the symmetric signature. In joint work with Gerd Laures and James McClure, we give a construction of such an L-homology fundamental class for those oriented singular spaces, which are integral intersection homology Poincaré spaces. Our approach constructs a morphism of ad theories from intersection Poincaré bordism to L-theory. We shall indicate an application to the stratified Novikov conjecture. The latter has been treated analytically by Albin, Leichtnam, Mazzeo and Piazza.

On the Hodge-Kodaira Laplacian on the canonical bundle of a compact Hermitian complex space

Francesco Bei

Hermitian complex spaces are a large class of singular spaces that include for instance projective varieties endowed with the metric induced by the Fubini-Study metric. Many of the problems raised by Cheeger, Goresky and MacPherson in the case of complex projective varieties admit a natural extension also in this setting. The aim of this talk is to report about some recent results concerning the Hodge-Kodaira Laplacian acting on the canonical bundle of a compact Hermitian complex space. More precisely let (X, h) be a compact and irreducible Hermitian complex space of complex dimension m. Consider the Dolbeault operator $\overline{\partial}_{m,0} : L^2\Omega^{m,0}(\text{reg}(X), h) \to L^2\Omega^{m,1}(\text{reg}(X), h)$ with domain $\Omega_c^{m,0}(\text{reg}(X))$ and let $\overline{\mathfrak{d}}_{m,0} : L^2\Omega^{m,0}(\text{reg}(X), h) \to L^2\Omega^{m,1}(\text{reg}(X), h)$ be any of its closed extension. Now consider the associated Hodge-Kodaira Laplacian $\overline{\mathfrak{d}}^* \circ \overline{\mathfrak{d}}_{m,0} : L^2\Omega^{m,0}(\text{reg}(X), h) \to L^2\Omega^{m,0}(\text{reg}(X), h)$. We will show that the latter operator is discrete and we will provide an estimate for the growth of its eigenvalues. Finally we will prove some discreteness results for the Hodge-Dolbeault operator in the setting of both isolated singularities and complex projective surfaces (without assumptions on the singularities in the latter case).

GLOBAL ANALYSIS ON THOM-MATHER SPACES

JOCHEN BRÜNING

This talk concerns the class of abstract stratified spaces known as Thom-Mather (TM-) spaces, which comprises e.g. simplicial complexes, algebraic varieties, and orbit spaces of proper Lie group actions on manifolds, and the classical Whitney stratified spaces. Generally, these spaces may be thought of as compactifications of a manifold by "adding" lower dimensional manifolds, possibly with common properties. As a very useful reference, one may consult John Mather's article [M] and the forgoing bibliography presented in the (illuminating) introduction by Mark Goresky (to the same issue of the Bulletin AMS).

It is of interest to develop differential geometry and elliptic theory on such spaces which presupposes, however, a certain amount of differential topology; the ground work can be found in [M], [V], and [BHS]. In this talk, I will concentrate on a flow version of the Ehresmann Theorem, and on the Whitney Embedding Theorem (into $\mathbb{R}^m$) and their extension to Thom-Mather spaces. I will also review some known and some new results in the global analysis of elliptic operators, in particular, the spectral and index theory of Dirac operators, on Thom-Mather spaces. Interestingly, these spaces find increasing attention in modern mathematical physics which may lead to fruitful applications and new questions for this area of research.

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Key words and phrases. Whitney Spaces, Thom-Mather-Spaces, Ehresmann-Theorem, Whitney-Imbedding of Thom-Mather-Spaces.

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Analysis, Geometry and Topology of Stratified Spaces

Xsenia Fedosova (Universität Bonn)

Analytic torsion of hyperbolic finite volume orbifolds

Abstract: The talk will be about the asymptotics of the analytic torsion of hyperbolic manifolds and orbifolds. The goal is to explain how the volume can be recovered from the asymptotics, following the work of Mller, Pfaff, and myself.

ALC MANIFOLDS WITH SPECIAL HOLONOMY

An ALC (asymptotically locally conical) manifold is a complete non-compact manifold with an end modelled on a circle fibration over a cone with fibres of asymptotically fixed finite length. ALC metrics are therefore special cases of fibred boundary metrics. When the asymptotic cone is flat the acronym ALF (asymptotically locally flat) is more commonly used.

The focus of the talk will be on complete Ricci-flat ALC manifolds with special homolomy. Interest for these ALC manifolds arises from the study of collapsing phenomena on compact manifolds with special holonomy. As motivation for this point of view I will describe the construction of sequences of hyperkähler metrics on the K3 surface collapsing to the flat orbifold $T^3/\mathbb{Z}_2$. The collapse occurs with bounded curvature outside finitely many point. The geometry around the points of curvature concentration is modelled on ALF gravitational instantons. This first part of the talk will be based on the pre-print arXiv:1603.06315.

In the second part of the talk I will discuss ALC manifolds with holonomy G_2. Cohomogeneity one examples have appeared in the physics literature since the early 2000's in connection with the duality between Type IIA String theory and M-theory. I will describe the analytic framework to study ALC G_2 manifolds and address in particular

(i) the deformation theory of ALC G_2 manifolds, and
(ii) the construction of examples of ALC G_2 manifolds beyond the symmetric case.

The second part of the talk is based on joint work with Mark Haskins (Imperial College London) and Johannes Nordström (University of Bath).

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Karsten Fritzsch (University College London)

The Neumann–Poisson Operator for Touching Hypersurfaces

Abstract: The Neumann–Poisson operator of a hypersurface in $\mathbb{R}^n$ arises from the restriction of the (Schwartz–) kernel of a fundamental solution of, for instance, the Laplacian to the hypersurface. As part of the method of layer potentials for solving the Dirichlet and Neumann problems, it has been studied extensively for over a century now. Due to its connection to transmission problems and relevance for applications in plasmonics, in the past decade there has been a rise in research focussing on the Neumann–Poisson operator associated not to a smooth hypersurface but to an embedded stratified space. Nevertheless, the theory of singular pseudodifferential operators has hardly been taken advantage of so far. In the situation of two touching hypersurfaces, we show that the Neumann–Poisson operator is a phi– pseudodifferential operator and use this calculus to derive mapping properties and to determine the essential spectrum.

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Colin Guillarmou (École Normale Supérieure, Paris)

Liouville Quantum Field Theory on Riemann surfaces

Abstract: the classical Liouville action on a closed Riemann surface is minimized by constant curvature metrics. Liouville Quantum Field Theory is the associated quantum field theory, which goes back to Polyakov in physics and amounts to summing over random surfaces. In joint work with Rhodes and Vargas, we define the partition function and correlation functions for this field theory, using the Gaussian Free Field and Gaussian Multiplicative Chaos, we prove this is a Conformal Field Theory. We then use this to define the Liouville Quantum Gravity partition function by averaging on the moduli space. This requires a precise analysis of the Gaussian Free Field near the boundary of the moduli space.

THE FRIEDRICHS EXTENSION FOR ELLIPTIC WEDGE OPERATORS OF SECOND ORDER

THOMAS KRAINER

Let M_0 be a smooth manifold without boundary, and let Y be a submanifold. Introducing polar coordinates in a tubular neighborhood of Y gives rise to a manifold M with boundary, where the boundary inherits a fibration $\wp : \partial M \to Y$ by spheres. Lifting differential operators from M_0 to M yields operators that are singular on the boundary ∂M. Wedge operators are a generalization of what is obtained by this process and are associated with generic manifolds M with boundary, where the boundary is fibred by smooth manifolds. Wedge operators arise naturally in the geometric analysis of stratified spaces, but there are many relevant examples outside of the realm of geometric operators that give rise to such operators as well (such as Schrödinger operators with singular potentials, elasticity equations, etc.). There is thus motivation to develop tools in sufficient generality to facilitate the analysis of generic wedge operators on manifolds with boundary and their iterated generalizations to manifolds with corners.

In this talk I plan to discuss a regularity result for a general elliptic wedge operator A of second order that is semibounded from below in $x^{-\gamma}L^2_b$ under some mild assumptions on its symbols. Here x is a defining function of the boundary, and $\gamma \in \mathbb{R}$ is an arbitrary weight. More precisely, we explicitly describe the domain $\mathcal{D}_F$ of the Friedrichs extension of A. We find that $\mathcal{D}_F$ fits into a split-exact sequence

$$0 \longrightarrow x^{-\gamma+2}H^2_e \longrightarrow \mathcal{D}_F \xrightarrow{T} H^{\mathfrak{g}}(Y;\mathcal{T}_F) \longrightarrow 0,$$

where $x^{-\gamma+2}H^2_e$ is the domain of the minimal extension of A in $x^{-\gamma}L^2_b$ (an edge Sobolev space), $\mathcal{T}_F \to Y$ is a smooth bundle that encodes the 'fibrewise' asymptotic behavior on the boundary and is governed by the indicial family of A, T is the (partial) Cauchy data map associated to A acting in $x^{-\gamma}L^2_b$ (what would correspond to Neumann data in a classical non-singular setting), and $H^{\mathfrak{g}}(Y;\mathcal{T}_F)$ is a Sobolev space of sections of $\mathcal{T}_F$ of variable anisotropic regularity as measured by the (canonical) vector bundle homomorphism $\mathfrak{g}$. The bundle $\mathcal{T}_F$ and the Sobolev space of sections of variable regularity provide the functional analytic framework to allow variable indicial roots of A and deal with their branching. The talk will be mainly descriptive.

This is joint work with Gerardo Mendoza (Temple University, Philadelphia).

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Fourier integral operators on Lie groupoids

Jean-Marie Lescure

In this talk we will present the content of two papers (arXiv:1502.02002, arXiv:1601.00932) as well as some results of a work under progress with S. Vassout.

Firstly, we will review the definition and basic examples of Lie groupoids. We will then explain the convolution of distributions on Lie groupoids and conclude this first part with a formula describing the wave front set of a convolution product. This formula uses, for a given Lie groupoid G, the *cotangent symplectic groupoid* structure of T^*G introduced by Coste, Dazord and Weinstein. This recovers the classical formulas for both the composition of distributional kernels on $X \times X$ and the convolution on a Lie group.

Secondly, we will turn to the developpement of a calculus for a suitable subclass, called G-FIO, of Lagrangian distributions on G. This class is chosen so that any G-FIO is a G-operator and moreover, under mild assumptions on the underlying Lagrangians, the composition (= convolution of the corresponding distributions on G) of two G-FIO is a G-FIO. The mentionned assumption is a transversality assumption ensuring that the product of two Lagrangians in T^*G remains Lagrangian and regular enough. This composition result together with a formula for the product of principal symbols is exactly the composition theorem of Hörmander for Lagrangian distributions on $X \times X$, if we take $G = X \times X$.

In the same spirit, C^*-continuity results are derived for G-FIO whose underlying Lagrangian is (locally) invertible: when their order is bounded by some explicit number, such G-FIO are bounded multipliers of $C^*(G)$. In particular, the corresponding operators in the fibers of G are bounded between suitable Hilbert spaces. These general constructions can be used to investigate Fourier integral operators on stratified spaces using the appropriate groupoids: we will illustrate this point in the simplest cases.

In the remaining time, going back to the general case, we will explain some work under progress about the equation $(\frac{\partial}{\partial t} + P)U = 0$, $U(0) = \mathrm{Id}$, where P is an order 1 positive elliptic G-pseudodifferential operator. We will see that the Hamiltonian flow of the principal symbol $\sigma(P) \in C^\infty(A^*G \setminus 0)$ leads to a Lagrangian, in a way rather similar to the manifold case but which uses some fundamental properties of the symplectic groupoid $T^*(\mathbb{R} \times G)$. Finally, we will conclude that the unique solution of the equation above is a $(\mathbb{R} \times G)$-FIO associated with this Lagrangian.

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Xiaonan Ma (Université Paris Diderot)

Bergman kernels on punctured Riemann surfaces

Abstract: Bergman kernels on punctured Riemann surfaces Abstract: we consider a punctured Riemann surface endowed with a Hermitian metric which equals the Poincare metric near the punctures and a holomorphic line bundle which polarizes the metric. We study the optimal uniform estimate of the supremum norm of a holomorphic L^2 section of the power of the line bundle when the power tends to infinite. We show that it can be localized around the singularities and its local model is the punctured unit disc endowed with the standard Poincaré metric.

Alexander-type invariants of hypersurface complements

Laurenţiu Maxim
University of Wisconsin-Madison

By analogy with knot theory, complex hypersurfaces can be studied via Alexander-type invariants of their complements. I will discuss old and new results concerning rigidity properties of such invariants, including twisted Alexander invariants, L^2-betti numbers and Novikov homology of hypersurface complements.

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Richard Melrose (MIT)

Planar Hilbert schemes and L^2 cohomology

Abstract: In this talk I will describe the 'metric compactification' of the Hilbert scheme of k unlabeled points in $\mathbb{C}^2$ as a resolution of the algebraic compactification with its stratification corresponding to clusters at infinity. The hyper-Kähler metric of Joyce and Nakajima is an iterated fibred boundary metric on the resulting manifold with corners as can be seen following the hyper-Kähler reduction given by Nakajima. Analysis of the Laplacian on this space allows the work of Carron on the topological identification of the L^2 cohomology, also using earlier results of Hitchin, to be extended to all k proving a conjecture of Vafa and Witten.

AN OBATA-LICHNEROWICZ THEOREM FOR STRATIFIED SPACES

In the first part of this talk we will show how classical tools of Riemannian geometry can be used in the setting of stratified spaces in order to obtain a lower bound for the spectrum of the Laplacian, under an appropriate assumption of positive curvature. Such assumption involves the Ricci tensor on the regular set and the angle along the stratum of codimension 2. We then show that a rigidity result holds when the lower bound for the spectrum is attained. These results, restricted to compact smooth manifolds, give a well-known theorem by M. Obata and A. Lichnerowicz.

Finally, we will explain some consequences of the previous theorems on the existence of a conformal metric with constant scalar curvature on a stratified space.

Analytic torsion for locally symmetric spaces of finite volume

Werner Müller

Abstract: This is joint work with Jasmin Matz. The goal is to introduce a regularized version of the analytic torsion for locally symmetric spaces of finite volume and higher rank. Currently we are able to treat quotients of the symmetric space $\mathrm{SL}(n, \mathbb{R})/\mathrm{SO}(n)$ by congruence subgroups of $\mathrm{SL}(n, \mathbb{Z})$. The definition of the analytic torsion is based on the study of the renormalized trace of the corresponding heat operators. The main tool is the Arthur trace formula. I will also discuss problems related to potential applications to the cohomology of arithmetic groups.

L_2-COHOMOLOGY AND THE THEORY OF WEIGHTS

LESLIE SAPER

ABSTRACT. The intersection cohomology of a complex projective variety X agrees with the usual cohomology if X is smooth and satisfies Poincare duality even if X is singular. It has been proven in various contexts (and conjectured in more) that the intersection cohomology may be represented by the L_2-cohomology of a Kähler metric defined on the smooth locus of X. The various proofs, though different, often depend on a notion of weight which manifests itself either through representation theory, Hodge theory, or metrical decay. In this talk we discuss the relations between these notions of weight and report on new work in this direction.

DUKE UNIVERSITY

ANALYTIC TORSION AND DYNAMICAL ZETA FUNCTION ON LOCALLY SYMMETRIC SPACES

SHU SHEN

Abstract: The relation between the spectrum of the Laplacian and the closed geodesics on a closed Riemannian manifold is one of the central themes in differential geometry. Fried conjectured that the analytic torsion, which is an alternating product of regularized determinants of the Hodge Laplacians, equals the zero value of the dynamical zeta function. In the first part of the talk, we will give a formal proof of this conjecture based on the path integral and Bismut-Goette's V-invariants. In the second part, we will give the rigorous arguments in the case where the underlying manifold is a closed locally symmetric space. The proof relies on the Bismut's formula for semisimple orbital integrals. This talk is based on a recent preprint arXiv:1602.00664.

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Michael Singer (University College London)

Monopole compactification and the Sen conjecture

Abstract: For each positive integer k, the moduli space M_k of nonabelian magnetic monopoles of charge k is a non-compact smooth manifold of dimension $4k$, carrying a natural hyperkaehler metric. The Sen conjecture, made in 1994, makes precise predictions about the existence of L^2 harmonic forms on these monopole moduli spaces, and necessarily requires a good understanding of the asymptotic structure of M_k and its metric. This is a challenging problem, not least because M_k has many different asymptotic regions, each associated to a partition of k. Recent work has brought the Sen conjecture within reach through the construction of a compactification of M_k as a manifold with corners. This can be viewed as a natural resolution of the stratification of the boundary arising from the different asymptotic regions. This is joint work with Karsten Fritzsch and Chris Kottke.

Recent Developments regarding Higher Rho invariants.
Shmuel Weinberger (University of Chicago)

Higher rho invariants are invariants of manifolds defined in a secondary way to Novikov's higher signatures, yet require a proof of the Novikov conjecture to define and also are only defined in the presence of appropriate acyclicity of the manifold (unlike ordinary rho invariants). They define invariants of structure groups. I will try to explain these invariants, their connection to Witt spaces, and some recent applications to the topology of manifolds that are close in Gromov-Hausdorff space. (This will be based on joint work with Dranishnikov and Ferry, and also with Xie and Yu.)

Simplicial homotopy theory for stratified spaces

Jon Woolf, joint work with Stephen Nand-Lal

May 2016

Simplicial sets form a combinatorial model for the homotopy theory of topological spaces; more precisely geometric realisation and the total singular complex functor are adjoint functors providing a Quillen equivalence between the Quillen model structure on simplicial sets and the (standard) one on topological spaces. Put another way, the model structure on topological spaces is obtained by transferring the Quillen model structure on simplicial sets across the above adjunction.

Fixing suitable stratifications of geometric simplices gives rise to stratified versions of geometric realisation and of the total singular complex functor, and hence to an adjunction between simplicial sets and stratified spaces. By transferring the Joyal (rather than the Quillen) model structure across this adjunction one obtains a model structure on stratified spaces. We claim that this model structure is a natural context in which to study the homotopy theory of stratified spaces. As evidence for this, its cofibrant-fibrant objects are closely related to Quinn's homotopically stratified spaces, and the resulting notion of homotopy equivalence between them is stratification-preserving homotopy.

The fibrant objects of Joyal's model structure are quasi-categories, the simplicial models of $(\infty, 1)$-categories. Results about these can be transferred across the above adjunction to obtain homotopy-theoretic results about stratified spaces. As an example, one obtains a version of a recent theorem due to David Miller which characterises stratification-preserving homotopy equivalences (between cofibrant-fibrant stratified spaces) as those maps which induce an isomorphism on posets of strata, and weak homotopy equivalences between corresponding strata and homotopy-links.

Min Yan

Title: Periodicity, Stratified Space, and Multiaxial Manifolds

Abstract: This is an expository talk on the fundamental role played by the periodicity in the surgery theory of topological manifolds and stratified spaces. I will first explain the homological view of the surgery exact sequence for topological manifolds. Then I will explain how this leads to the surgery theory of homotopically stratified spaces. Finally, I will explain the stratified interpretation of the periodicity and the application of the interpretation to the study of multiaxial manifolds.