BOOK OF ABSTRACTS

SS20 - Global Analysis and Geometry of semi-Riemannian Manifolds

2nd Joint Meeting Brazil-Italy in Mathematics

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Messina, Italy

Organizers:

Giovanni Calvaruso, University of Salento
Anna Maria Candela, University of Bari
Viviana del Barco, Universidade Estadual de Campinas
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Rigidity for Serrin's Problem in Riemannian manifolds

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This talk presents results on Serrin's overdetermined problems in Riemannian manifolds. For manifolds endowed with a conformal vector field, we prove a Pohozaev-type identity to establish a Serrin-type rigidity result using the P-function approach introduced by Weinberger. This is joint work with Allan Freitas (UFPB, Brazil) and Diego Marín (Universidad de Granada, Spain).

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Into the indefinite

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In the context of homogeneous Einstein metrics, stepping out of the definite world one is confronted by many strange beasts. Parallel distributions that do not split a de Rham factor [1]; Ricci-flat metrics that are not flat [2]; Einstein solvmanifolds not originating from a nilsoliton [3]; Einstein *nil*manifolds, even [4].

The pseudo mathematician can only marvel at this vast diversity, and explore it constructively, as I shall endeavour to do in this talk; for I know that there *are* theorems to be found in this indefinite land; but they must be sought in the folds of special geometries, whilst the general landscape defies any hope of classification.

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A new approach to the classification of almost contact metric manifolds

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Almost contact metric manifolds are odd dimensional Riemannian manifolds (M^{2n+1}, g) whose structural group is reducible to $U(n) \times 1$. They have been intensively studied in the last decades, as odd dimensional counterparts of almost Hermitian manifolds (see Blair's monograph [2] and references therein). Some special classes, such as Sasakian, cokähler, or quasi-Sasakian manifolds which include both, have seen a great development, also because of their natural occurrence as one-dimensional fibrations, even in the cases where the transverse geometry with respect to the Reeb foliation is not Kähler.

One difficulty in dealing with almost contact metric geometry is the huge amount of different classes of manifolds that can be defined, with a great variety of geometric properties. In 1990 a classification into 2^{12} classes of almost contact metric manifolds was provided by D. Chinea and C. Gonzalez [2], based on the behaviour of the covariant derivative $\nabla^g \Phi$ of the fundamental 2-form Φ associated to the structure (φ, ξ, η, g), with respect to the Levi-Civita connection. This is an analogue of the Gray-Hervella classification of almost Hermitian manifolds. In fact, among the 12 irreducible classes $\mathcal{C}_1, \dots, \mathcal{C}_{12}$ defined by Chinea-Gonzalez, the first four $\mathcal{C}_1, \dots, \mathcal{C}_4$ correspond to Gray-Hervella's classes $\mathcal{W}_1, \dots, \mathcal{W}_4$.

In this talk I will present a new approach to almost contact metric manifolds recently described in [1], based on two *intrinsic* endomorphisms S and h, which bear their name from the fact that they are, basically, the entities appearing in the intrinsic torsion. The new classification scheme is given by a simple flowchart based on algebraic conditions involving S and h; the scheme naturally leads to a regrouping of the Chinea-Gonzalez classes, and, in each step, to a further refinement, eventually ending in the single irreducible classes. This method allows a more natural exposition and derivation of both known and new results.

First one can describe in detail the remarkable (and still very large) subclass $\mathcal{C}_5 \oplus \ldots \oplus \mathcal{C}_{12}$ of *$\mathcal{H}$-parallel* almost contact manifolds, defined by the condition $(\nabla^g_X \Phi)(Y, Z) = 0$ for all horizontal vector fields, X, Y, Z. Furthermore, we completely characterize, in terms of the Chinea-Gonzalez classes, the almost contact metric manifolds admitting a *characteristic connection*, namely the unique metric connection with totally skew-symmetric torsion adapted to the structure. This problem has remained open since the seminal work of T. Friedrich and S. Ivanov [4], whereas analogous characterizations were already known for almost Hermitian manifolds and G_2-manifolds.

This is a joint work with Ilka Agricola, Dario Di Pinto, and Marius Kuhrt.

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Left-invariant G_2^*-structures of type III

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We will discuss left-invariant G_2^*-structures on 7-dimensional Lie groups, focusing on those whose holonomy algebras are indecomposable and of type III, the latter meaning that the socle of the holonomy representation is maximal. We will answer the question of which ones arise as infinitesimal holonomy algebras of type III for left-invariant G_2^*-structures, showing that only abelian subalgebras occur, and these are necessarily of dimension two or three. We will also provide explicit Lie groups with left-invariant G_2^*-structures realizing these abelian holonomies.

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A New Construction Related to Twistor Spaces

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Twistor theory was initiated by R. Penrose [3] in the 1960s as a tool to transform solutions of certain physical nonlinear differential equations into holomorphic objects, which can be studied with the tools of complex geometry. The theory was formalized and generalized by Atiyah, Hitchin, and Singer in [1].

In this talk, I will review the geometry of twistor space and present a recent construction obtained in collaboration with G. Grantcharov and A. Pipitone in [2]. The construction can be viewed as a modification of the twistor space associated with a scalar-flat Kähler surface M.

I will show that this modification admits complete balanced metrics. Moreover, it cannot be Kähler when M is a compact simple hyperkähler manifold.

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Einstein metrics and Killing spinors on pseudo-Riemannian solvmanifolds

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A Killing spinor on a pseudo-Riemannian spin manifold (M, g) is a non-zero spinor field ψ satisfying $\nabla_X \psi = \lambda X \cdot \psi$ for some constant $\lambda \in \mathbb{C}$. The existence of such a spinor strongly constrains the geometry: for example, in the Riemannian case it forces the metric to be Einstein. In indefinite signature this is no longer the case: a Killing spinor need not make the metric Einstein, so the two conditions become genuinely independent, and the interplay between them is the question we address.

In this talk we focus on pseudo-Riemannian metrics on homogeneous manifolds admitting a Killing spinor, not necessarily invariant under the isometry group. We work with solvmanifolds, and in particular with the pseudo-Iwasawa ones, where the solvable Lie algebra splits orthogonally as a nilpotent ideal and an abelian factor acting by symmetric derivations.

Our main results are twofold (see [4]). First, we construct an explicit family $\tilde{G}^{a,k}$ of pseudo-Iwasawa solvmanifolds carrying a Killing spinor in every dimension and signature. Second, we prove the converse: every pseudo-Iwasawa solvmanifold with a Killing spinor belongs to this family; and is Einstein only for the hyperbolic half-space. Specializing our result to the Riemannian case, and using known results of Böhm–Lafuente on homogeneous Einstein manifolds and of Baum on manifolds with imaginary Killing spinors, we obtain that the only homogeneous Riemannian manifold admitting a Killing spinor with λ imaginary is hyperbolic space.

Producing genuinely new Einstein solvmanifolds with a Killing spinor thus requires stepping outside the pseudo-Iwasawa regime. This is indeed possible: the pseudo-Riemannian Sasaki–Einstein solvmanifolds of [1,2] are never of pseudo-Iwasawa type, and further examples arise from the classification of low-dimensional harmful structures of [3].

This talk is based on joint work with D. Conti and R. Segnan Dalmasso ([4]).

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On the inverse mean curvature flow by parallel hypersurfaces in space forms

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We consider the inverse mean curvature flow by parallel hypersurfaces in space forms. We show that such a flow exists if and only if the initial hypersurface is isoparametric. The flow is characterized by an algebraic equation satisfied by the distance function of the parallel hypersurfaces. The solutions to the flow are obtained explicitly when the distinct principal curvatures have the same multiplicity. This is an additional assumption only for isoparametric hypersurfaces of the hyperbolic space or of the sphere with two or four distinct principal curvatures. The boundaries of the maximal interval of definition, when finite, are determined in terms of the number g of distinct principal curvatures, their multiplicities m and the mean curvature H of the initial hypersurface. We describe the collapsing submanifolds of the flow at the boundaries of the interval. In particular, for such hypersurfaces of the sphere, we describe the collapsing minimal hypersurfaces.

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