XXIV International Fall Workshop  
on Geometry and Physics  

September 1-4, Zaragoza, Spain

Book of abstracts
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## Part I

### SCHEDULE

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<td>9:30 – 10:00</td>
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<td>D. Peralta</td>
<td>D. Peralta</td>
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<td>S. Gutt</td>
<td>M. Jotz Lean</td>
<td>J. Palacián</td>
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<td>A. De Nicola</td>
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Part II
MINICOURSES

Advanced Quantum Mechanics

VALTER MORETTI

UNIVERSITY OF TRENTO, ITALY
e-mail: moretti@science.unitn.it

Abstract

The idea of the mini-course is to review the formulation of quantum theories from an advanced viewpoint, essentially based on the orthomodular lattice of elementary propositions due to von Neumann, discussing some fundamental ideas, mathematical tools and theorems in particular related to the representation of physical symmetries (Gleason, Wigner-Kadison, Stone Stone-von Neumann, Garding, Nelson, Bargmann...). The final step consists of an elementary introduction to the so-called ($C^*$-) algebraic formulation of quantum theories.

Knots and links in fluid mechanics

DANIEL PERALTA

ICMAT, SPAIN
e-mail: dperalta@icmat.es

Abstract

The goal of this course is to introduce certain geometric aspects of ideal fluid flows. We shall mainly focus on the existence of knotted and linked stream lines in stationary solutions of the Euler equations. In particular, we shall review the celebrated Arnold’s structure theorem and the realization theorems of knots and links in Beltrami flows obtained by A. Enciso and the speaker.
Part III
INVITED LECTURES

Topological phases and topological insulators

MANUEL ASOREY

UNIVERSIDAD DE ZARAGOZA, SPAIN
e-mail: asorey@unizar.es

Abstract

We review the characteristics of states of matter where the relevant order parameters are topological invariants. In these phases there are no local degrees of freedom and the only observables are topological invariants. An interesting effect of topological phases is the appearance of topological insulators, which are a new type of insulators with conducting boundaries. We shall analyse the role of edge states in the interface of two different phases and its implications for topological insulators.

Flexible phenomena in symplectic geometry

ROGER CASALS

MIT, USA
e-mail: casals.roger@icmat.es

Abstract

In this talk we discuss recent advances in the flexible side of symplectic and contact topology. In particular we prove a criterion that characterizes overtwisted contact structures, and relate Dehn twists to flexible Weinstein domains. We first provide the necessary definitions and properties involved in the theorems, and then present the proof of the main results. Finally, we explore consequences and applications to Hamiltonian mechanics.
Geometry of Lie integrability by quadratures

FERNANDO FALCETO

UNIVERSIDAD DE ZARAGOZA, SPAIN
e-mail: falceto@unizar.es

Abstract

In this talk we present an extension of the Lie theory of integration by quadratures in two steps. First we consider a finite-dimensional Lie algebra of vector fields and discuss the most general conditions under which the integral curves of one of the fields can be obtained by quadratures in a prescribed form. It turns out that the conditions can be expressed in a purely algebraic way, that contains as a particular case the Lie theorem. In a second step we generalize the construction by considering, instead of a Lie algebra of vector fields, a module (generalized distribution). We obtain a much larger class of integrable systems replacing standard concepts of solvable (or nilpotent) Lie algebra with distributional solvability (nilpotency).


A symplectic framework for Radon-type transforms

SIMONE GUTT

UNIVERSITY LIBRE DE BRUXELLE, BELGIUM
e-mail: sgutt@ulb.ac.be

Abstract

Darboux’s theorem states that any symplectic manifold is locally symplectomorphic to an open set in the space $\mathbb{R}^{2n}$ with its canonical symplectic form. There are thus no local invariants. Nevertheless, it is interesting to study symplectic connections and in particular to determine which symplectic manifolds admit symplectic connections with special properties. We shall present here in the symplectic framework an analogue to the classical constant sectional curvature condition in (pseudo)-Riemannian geometry.
the class of connected simply connected symmetric symplectic manifolds endowed with a Ricci-type connection. We give models of such spaces. Those spaces have a nice submanifold theory and they possess a large number of totally geodesic submanifolds which we describe. This gives a nice framework for possible Radon-type transforms.

On the correspondence of Lie 2-algebroids and VB-Courant algebroids

Madeleine Jotz Lean

University of Sheffield, UK
e-mail: m.jotz-lean@sheffield.ac.uk

Abstract

Linear connections are useful for describing the tangent spaces of vector bundles, especially their Lie algebroid structure. The direct sum of the tangent space and the cotangent space of a manifold carries the structure of a “standard Courant algebroid”, which naturally extends the Lie algebroid structure of the tangent space. In geometric mechanics, it is often useful to understand the standard Courant algebroid over a vector bundle (e.g., a phase space $T^*Q$). I will introduce the notion of “Dorfman connection” and explain how the standard Courant algebroid structure over a vector bundle is encoded by a certain class of Dorfman connections. Then I will explain how this is in fact a special case of a more general equivalence between Lie 2-algebroids and VB-Courant algebroids (its existence is due to Severa and Li-Bland). I will illustrate with one further example why this new geometric intuition is useful in the study of Lie $n$-algebroids.
Singular Reduction for Hamiltonian Systems: Dynamics on Orbifolds and Reconstruction

Jesús Palacín

Universidad Pública de Navarra, Spain
e-mail: palacian@unavarra.es

Abstract

The problem we discuss has been a testing ground for many different methods for analysing Hamiltonian systems and in particular finding periodic solutions and their stability. Here we illustrate the use of singular reduction on this classic problem. Singular reduction lowers the dimension of the problem under study; so, given that our first test problem is a two-degree-of-freedom Hamiltonian system in $\mathbb{R}^4$, it will be reduced to a Hamiltonian system of one degree of freedom on a two-dimensional real algebraic surface called an orbifold. The two-dimensionality leads itself to a graphical representation with a better geometric insight on the flow of the full system.

The planar restricted three-body problem is considered as a benchmark for the last 85 years, and in particular there has been a bunch of works, mainly of numerical type, to obtain the periodic solutions and related invariant manifolds around the equilibrium points $L_4$ and $L_5$. We shall illustrate how reduction theory is used to establish rigorously the existence and stability of these solutions, as well as the different types of bifurcations.

Then we shall jump to $n$ degrees of freedom with $n \geq 3$ where the polynomial invariants needed in the singular reduction theory are determined using an algorithm based on integer programming. After computing these invariants we use Gröbner bases theory and the division algorithm for multivariate polynomials to deal with the equations of motion in terms of the invariants. We shall apply the theory with the aim of finding some periodic solutions in resonant Hamiltonian systems of $n$ degrees of freedom with semisimple linear part.

This is a joint work with Ken R. Meyer and Patricia Yanguas.
Almost regular Poisson structures

MARCO ZAMBÓN

KU LEUVEN, BELGIUM
e-mail: marco.zambon@wis.kuleuven.be

Abstract

We introduce almost regular Poisson structures, which have as special cases regular Poisson structures and b-symplectic structures. We show that the almost regular Poisson manifolds are exactly those whose (singular) symplectic foliation admits a smooth holonomy groupoid, and show that the latter is actually a Poisson groupoid. This talk is based on current work with Androulidakis.

Dirac-Kaehler operators on spheres

ALESSANDRO ZAMPINI

UNIVERSITÉ DU LUXEMBOURG, LUXEMBOURG
e-mail: alessandro.zampini@uni.lu

Abstract

In this talk I shall review the Kaehler construction of the Dirac operator, compare it with that arising in the usual spin manifold formulation, and apply the formalism to construct Dirac operators globally defined on a class of spheres.
Part IV
CONTRIBUTED TALKS

An integrable Hénon–Heiles system on spaces with constant curvature

Ángel Ballesteros\textsuperscript{a}, A. Blasco, Francisco J. Herranz and Fabio Musso

\textsuperscript{a} Universidad de Burgos, Spain
e-mail: angelb@ubu.es

Abstract

It is well known that the following multiparametric generalization of the two-dimensional Hénon–Heiles Hamiltonian system

\[ H = \frac{1}{2}(p_1^2 + p_2^2) + \Omega_1 q_1^2 + \Omega_2 q_2^2 + \alpha(q_1^2 q_2 + \beta q_2^3), \]

has only three Liouville integrable cases, namely:

- The Sawada–Kotera Hamiltonian case ($\beta = \frac{1}{3}; \Omega_1 = \Omega_2$).
- The Korteweg–de Vries (KdV) case ($\beta = 2$, $\Omega_1$ and $\Omega_2$ arbitrary).
- The Kaup–Kupershmidt case ($\beta = \frac{16}{3}; \Omega_2 = 16\Omega_1$).

In this contribution we present a constant curvature analogue $H_k$ of the integrable KdV Hénon–Heiles Hamiltonian with $\Omega_2 = 4\Omega_1$, and of its corresponding invariant $I_k$ [1]. Our approach is based on the use of the constant Gaussian curvature $k$ of the underlying spaces as an explicit deformation parameter [2, 3]. This allows us to present this curved Hénon–Heiles Hamiltonian in a unified geometric approach that contains, simultaneously, the spherical and hyperbolic cases, and from which the Euclidean system is obtained in the at limit $k \to 0$.

In particular, the starting point for the construction will be the curved anisotropic oscillator proposed in [3], that under the specific tuning in the frequencies $\Omega_2 = 4\Omega_1$ coincides with the well-known superintegrable curved $1:2$ oscillator system obtained in [2]. From the latter, the curved version of the Ramani–Dorizzi–Grammaticos homogeneous potentials [4] can be obtained, and the Hénon-Heiles system arises by considering
the curved analogue of the cubic term [1]. This strategy seem to be applicable to the other two integrable cases, but the appropriate curved anisotropic oscillator has to be found.

References


Lorentzian Homogeneous Gradient Ricci Solitons

MIGUEL BROZOS VÁZQUEZ

UNIVERSIDADE DA CORUÑA, SPAIN

e-mail: mbrozos@udc.es

Abstract

A gradient Ricci soliton is a triple $(M, g, f)$ where $(M, g)$ is a pseudo-Riemannian manifold and $f : M \to R$ is a function satisfying the Ricci soliton equation

$$Hes_f + \rho = \lambda g$$

where $Hes_f$ denotes the Hessian of $f$, $\rho$ denotes de Ricci tensor and $\lambda$ is a real number. In this talk we will see some rigidity results for locally homogeneous Lorentzian
gradient Ricci solitons and give evidence of important differences with the Riemannian setting. More specifically, we will describe the structure of the Ricci tensor on a locally homogeneous Lorentzian gradient Ricci soliton. In the non-steady case, we will show that the soliton is rigid in low dimensions. In the steady case, we will give a complete classification in dimension three.

**Hard Lefschetz theorem for Vaisman manifolds**

**Antonio de Nicola**\(^a\), B. Cappelletti-Montano\(^b\), J.C. Marrero\(^c\) and I. Yudin \(^a\)

\(^a\) CMUC, University of Coimbra, Portugal  
e-mail: antondenicola@gmail.com  
e-mail: yudin@mat.uc.pt

\(^b\) Università degli Studi di Cagliari, Italy  
e-mail: b.cappellettimontano@gmail.com

\(^c\) Unidad Asociada ULL-CSIC Geometría Diferencial y Mecánica Geométrica, Universidad de La Laguna, Spain  
e-mail: jcmarrer@ull.edu.es

**Abstract**

It is well known that in any compact Kähler manifold the exterior multiplication by a suitable power of the symplectic form induces isomorphisms between the de Rham cohomology spaces in complementary degrees. This is the celebrated Hard Lefschetz Theorem [2]. In my talk I will present a version of the Hard Lefschetz theorem for compact locally conformal Kähler manifolds with parallel Lee vector field, known as Vaisman manifolds. Our result is based on the Hard Lefschetz theorem for Sasakian manifolds [1] and the fact that any compact Vaisman manifold is the mapping torus of a compact Sasakian manifold [3].

**References**

Dynamics on the Space of States:
 a Geometrical Description

J.A. JOVER-GALTIER

UNIVERSIDAD DE ZARAGOZA, SPAIN
e-mail: jorge.jover@bifi.es

Abstract

I will present a picture of Quantum Mechanics based on the geometrical description of physical observables in terms of expectation value functions, thus generalizing the so-called Ehrenfest picture of quantum systems. The basic geometrical tools reproduce the Hermitian structure of the Hilbert space and incorporate in a natural way the probabilistic description of Quantum Mechanics. The geometrical formalism allows us to analyze from a new perspective the properties of quantum systems, such as dynamical equations, uncertainty relations, coherent states and the non-unitary evolution of open systems.

References


Hamiltonian dynamics of parametrized field theories with boundaries

JUAN MARGALEF

UC3M, Spain
e-mail: juan.margalef@uc3m.es

Abstract

Parametrized field theories are interesting non-linear infinite-dimensional dynamical systems where, in addition to the standard field degrees of freedom, spacetime foliations are also included in the set of dynamical variables. In their Hamiltonian formulation these models include spacelike embeddings of the space manifold into spacetime as configuration variables. The classical treatment of these systems goes back to Dirac [1] and has been developed by Kuchar, Hajicek and Isham [2, 3] among other authors. They have been used to discuss interesting problems –in particular the problem of time– that play a significant role in quantum field theory. From the quantum point of view it has received attention in the loop quantum gravity framework because of its diffeomorphism invariance [4, 5].

In a search of field models with boundary observables, several authors [6] have recently considered the Hamiltonian formulation for the parametrized scalar field in the presence of boundaries with different types of boundary conditions including Dirichlet and Robin. However the lack of a proper geometric understanding of the system makes it difficult to interpret their results and obtain a complete Hamiltonian description. In this talk we address this problem and discuss several important points regarding the detailed Hamiltonian formulation [7] for parametrized scalar fields in bounded domains that have been missed up to now. We do this by relying on the geometric algorithms developed by Gotay, Nester and Hinds [8]. In order to deal with the presence of embeddings among the configuration variables describing these systems we will also rely on the powerful geometric methods developed by Bauer, Michor and collaborators [9]. We will identify the constraint submanifold in phase space where the dynamics takes place and explicitly construct the Hamiltonian vector fields that define the dynamics. The methods and ideas presented here can be generalized to other parametrized field models involving standard gauge symmetries.
Hermitian Metrics on solvmanifolds with holomorphically trivial canonical bundle

ANTONIO OTAL

CENTRO UNIVERSITARIO DE LA DEFENSA DE ZARAGOZA, SPAIN

e-mail: aotal@unizar.es

Abstract

A complex manifold $X$ is said to have holomorphically trivial canonical bundle if it admits a non-vanishing holomorphic volume form. This kind of complex geometry has interest in the study of heterotic string theory since such complex manifolds (endowed with a Hermitian balanced metric $F$, i.e. $F^{n-1}$ is closed, where $F$ denotes the Kähler form and $n = \dim_{\mathbb{C}} X$) constitute the geometric background of the Strominger system [7].

It turns out that any compact complex surface with holomorphically trivial canonical bundle is isomorphic to a K3 surface, a torus, or a Kodaira surface; the first two are Kähler, and the latter is a nilmanifold, i.e. a compact quotient of a nilpotent Lie
group by a lattice. It is well known that in any real dimension \(2n\) the canonical bundle of a nilmanifold \(G/\Gamma\) endowed with an invariant complex structure is holomorphically trivial, where by invariant complex structure we mean one induced by a complex structure \(J\) on the Lie algebra of the nilpotent Lie group \(G\). In fact, it is proved in [6] the existence of a non-vanishing invariant holomorphic volume form providing a big source of compact examples. For 6-dimensional nilmanifolds the classification of invariant complex structures \(J\) as well as the existence of some special Hermitian metrics (such as Strong Kähler with torsion or balanced metrics among others) with respect to such \(J\)'s have been studied in [1, 3, 4].

It is natural to extend the previous works in the bigger class of solvmanifolds, that is, homogeneous spaces obtained as a compact quotient of a solvable Lie group by a lattice. In this work we show the results obtained in [2] concerning the Hermitian geometry of 6-dimensional solvmanifolds admitting an invariant complex structure with holomorphically trivial canonical bundle, paying attention to the Hermitian geometry on the complex parallelisable Nakamura manifold [5] and a non-finite family of complex structures on it.

References


Geometric description of Quantum Systems in a classical-like Hamiltonian picture and applications

Davide Pastorello

University of Trento and INFN, Italy
e-mail: pastorello@science.unitn.it

Abstract

Adopting a geometric classical-like point of view on Quantum Mechanics is an intriguing idea since we know that geometric methods are very powerful in Classical Mechanics thus we can try to use them to study quantum systems. There are interesting approaches, like quantizer-dequantizer scheme in tomographic picture, to formulate Quantum Mechanics within a phase space framework. In [2] we have considered a quantum system described in a finite-dimensional Hilbert space and we have constructed a general prescription to set up a well-defined and self-consistent Hamiltonian description of such system where the phase space is given by the Hilbert projective space (as Kähler manifold), in the spirit of celebrated works of T.W.B. Kibble, G.W. Gibbons, A. Ashtekar and others. This Hamiltonian formulation can be defined classical-like because quantum observables are represented by a class of real scalar functions, quantum states are described by Liouville densities (normalized probability densities), and Schrödinger dynamics is induced by a Hamiltonian flow on the projective space. The star-product of this phase space formulation has been explicitly constructed [2].

After an introduction on such quantum/classical-like correspondence, this talk focuses on recent results published in [1] like the re-quantization scheme to obtain the standard quantum formalism from the proposed geometric Hamiltonian one acting on classical-like objects with operator-valued distributions. Then description of composite quantum systems will be discussed, in particular how tensor product of operators can be translated in a new binary operation on phase space functions. The machinery to implement separability criteria for mixed states and notions like entanglement witness in our geometric approach will be presented. Since topic of the talk is focused on finite-dimensional Quantum Mechanics, an interesting application is a new geometric approach to quantum control theory where \( n \)-level systems are tipically considered. Classical control theory is a huge and rich theory thus one can suppose to use some powerful classical tools to describe controllability of a quantum system within the geometric Hamiltonian picture.
Integrability approaches of differential equations

Cristina Sardón

Universidad de Salamanca, Spain
e-mail: cristinasardon@usal.es

Abstract

On a first approximation, the universal definition of integrability is understood as the exact solvability or regular behavior of solutions of a system. Nevertheless, there are various distinct notions of integrable systems. The characterization and unified definition of integrability are two nontrivial matters. The study of integrability from several different perspectives has led to an apparent fragmented notion of them. The aim of this introduction is to give a comprehensive account of the variety of approaches to such an important concept as that of integrability. In particular, we will focus on approaches applicable to mathematical and physical models described through ODEs and PDEs.
Cohomogeneity one hypersurfaces in the complex projective and hyperbolic planes

Cristina Vidal Castiñeira

Universidade de Santiago de Compostela, Spain

e-mail: cristina.vidal@usc.es

Abstract

A Riemannian manifold is said to be of cohomogeneity one if it admits an isometric action with some orbit of codimension one [3]. Gorodski and Gusevskii [2] obtained examples of complete cohomogeneity one hypersurfaces with constant mean curvature in the complex hyperbolic plane. Recently, in a joint work with Díaz-Ramos and Domínguez-Vázquez [1], we found the first examples of hypersurfaces with exactly two nonconstant principal curvatures in the complex projective and hyperbolic planes. All these examples have a common property: they are hypersurfaces of cohomogeneity one. In fact, they all admit a Riemannian foliation by Lagrangian surfaces with parallel mean curvature.

In this talk I will explain a geometric property -natural generalization of the notion of Hopf hypersurface- which allows us to characterize all these examples of cohomogeneity one hypersurfaces.

References


Dirac-Jacobi bundles

LUCA VITAGLIANO

UNIVERSITÀ DEGLI STUDI DI SALERNO, ITALY
e-mail: lvitagliano@unisa.it

Abstract

I propose a definition of Dirac-Jacobi structure on a generic (i.e. non-necessarily trivial) line bundle. Dirac-Jacobi structures on line bundles generalize Wades $E^1(M)$-Dirac structures and unify generic (i.e. non-necessarily coorientable) precontact distributions, Dirac structures and local Lie algebras with one dimensional fiber in the sense of Kirillov (in particular, Jacobi structures in the sense of Lichnerowicz). I will discuss the main properties of Dirac-Jacobi bundles and prove that integrable Dirac-Jacobi structures on line-bundles integrate to (non-necessarily coorientable) precontact groupoids. This puts in a conceptual framework several results already available in literature for $E^1(M)$-Dirac structures.

References


An intrinsic version of the biharmonic equation via the Legendre transformation

Lígia Abrunheiro\textsuperscript{a} and Margarida Camarinha\textsuperscript{b}

\textsuperscript{a} CMUC, University of Coimbra, Portugal  
e-mail: mmlsc@mat.uc.pt

\textsuperscript{b} CIDMA, University of Aveiro, Portugal  
e-mail: abrunheiroligia@ua.pt

Abstract

The notion of the Riemannian cubic polynomial is associated with a second order variational problem depending on the covariant acceleration. The Euler-Lagrange equation of this problem is called biharmonic. As mentioned by Bucataru, one can associate different non-linear connections with this equation and study the corresponding geometry of the problem. In this work, we consider a geometric formulation of the second order variational problem and describe a generalized Legendre transformation defined from the third order tangent bundle $T^3M$ to the cotangent bundle $T^*TM$, with $M$ as the configuration manifold. The intrinsic version of the Euler-Lagrange equation and the corresponding Hamiltonian equation obtained via the Legendre transformation are presented here. We also explore the repercussions of this construction for the geometry of the problem.

References


**R-flux twisted Poisson quasi-Nijenhuis structures**

**Paulo Antunes**

CMUC, University of Coimbra, Portugal
e-mail: pantunes@mat.uc.pt

We characterize generalizations of Poisson-Nijenhuis structures on Lie algebroids as complex endomorphisms of Courant algebroids. We recover some structures and results already studied in [1, 2, 3] but, in some cases, we obtain the twist of these known structures by a (so-called) $R$-flux.

**References**


The Modular Class of a Lie $n$-algebra

RAQUEL CASEIRO

CMUC, UNIVERSITY OF COIMBRA, PORTUGAL
e-mail: raquel@mat.uc.pt

Abstract

The modular class of a Lie $n$-algebra is introduced and some of its properties are proven.

References


On some classes of immersions into tangent bundle

STANISLAW EWERT-KRZEMIENIEWSKI

WEST POMERANIAN UNIVERSITY OF TECHNOLOGY SZCZECIN, POLAND
e-mail: Stanislaw.Ewert-Krzemieniewski@zut.edu.pl

Abstract

The isometric immersion $f : (M, g) \rightarrow (N, \bar{g})$ of Riemannian manifolds gives rise in a natural way to immersions $\tilde{f} : TM \rightarrow TN$ of its tangent bundles equipped with non-degenerate $\bar{g}$–natural metric $\bar{G}$. We propose investigation of such immersion generated either by vector fields tangent to $M$ or its van der Waerden-Bertolotti covariant derivative or by the Levi-Civita connection of the induced metric $g$. 
Ricci solitons associated to the $k$-th generalized Tanaka-Webster connections

GEORGE KAIMAKAMIS$^a$, KONSTANTINA PANAGIOTIDOU$^a$ AND JUAN DE DIOS PÉREZ$^b$

$^a$ HELLenic MILITARY aCADemy, greece
e-mail: gmiamis@gmail.com
e-mail: konpanagiotidou@gmail.com

$^b$ Universidad de Granada, Spain
e-mail: jdperez.ugr.es

Abstract

A real hypersurface $M$ in a non-flat complex space form $M_n(c)$, $c \neq 0$, is an immersed submanifold with real codimension equal to 1. An almost contact metric structure $(\phi, \xi, \eta, g)$ can be defined on $M$, which is induced from the Kaehler metric $G$ and the complex structure $J$ of $M_n(c)$. On real hypersurfaces the $k$-th generalized Tanaka-Webster connection is defined in the following way

$$\hat{\nabla}_X^k Y = \nabla_X Y + g(\phi AX, Y)\xi - \eta(Y)\phi AX - k\eta(X)\phi Y,$$

for any tangent vector field $X$, $Y$ on $M$ and $k$ is a non-zero real number. The aim of this poster is to present a new type of Ricci solitons of real hypersurfaces in $M_n(c)$ associated to the $k$-th generalized Tanaka-Webster connection of those, called $k$-th generalized Tanaka-Webster Ricci solitons. It will be answered if there are real hypersurfaces in $M_n(c)$ admitting $k$-th generalized Tanaka-Webster Ricci solitons [1]. Finally, results concerning real hypersurfaces in non-flat complex space forms in terms of their generalized Tanaka-Webster Ricci tensor will be given [2].
References


Recovering invariant complex structures on 6-dimensional nilmanifolds

Adela Latorre\textsuperscript{a}, Luis Ugarte\textsuperscript{a} and Raquel Villacampa\textsuperscript{b}

\textsuperscript{a} Universidad de Zaragoza, Spain
e-mail: adela@unizar.es
e-mail: ugarte@unizar.es

\textsuperscript{b} Centro Universitario de la Defensa de Zaragoza, Spain
e-mail: raquelvg@unizar.es

Abstract

The Newlander-Nirenberg Theorem allows to identify every complex manifold $X^n$ with a pair $(M^{2n}, J)$, where $M$ is a differentiable manifold and $J$ is a complex structure on it. Therefore, the problem of finding and classifying these pairs turns to be a key point in Complex Geometry. Although this is not an easy task, the issue can be slightly simplified when $M$ is a nilmanifold and $J$ is invariant. The reason is that one can then work on the nilpotent Lie algebra $g$ underlying $M$ and focus on those complex structures $J$ defined on it. The classification of the pairs $(g; J)$ has already been accomplished in dimensions four and six. We propose here a new method which allows one to recover them from a different point of view. We believe that it could cast some light into the higher dimensional problem, where there is no classification of nilpotent Lie algebras.
Natural operations on differential forms

José Navarro and Juan B. Sancho

Universidad de Extremadura, Spain
e-mail: navarroarmendia@unex.es

Abstract

I will explain the main results in [3], which, roughly speaking, say that the only natural operations between differential forms are those obtained using linear combinations, the exterior product and the exterior differential. These results generalise work by Palais ([4]) and Freed-Hopkins ([1]).

As an application, I will also obtain a theorem, originally due to Kolář ([2]), that determines those natural differential forms that can be associated to a connection on a principal bundle.

References


On holomorphic Riemannian geometry and submanifolds of Wick-related spaces

**Victor Pessers**

KU Leuven University, Belgium
e-mail: Victor.Pessers@wis.kuleuven.be

**Abstract**

A method will be presented that provides direct relationships between certain submanifolds of one pseudo-Riemannian space to submanifolds of another pseudo-Riemannian ambient space, under the condition that ambient spaces are so-called ‘Wick-related’. Our approach seems new in the area of submanifold theory, although it incorporates several existing insights, such as the theory on analytic continuation, complex Riemannian geometry and real slices, as well as the method of Wick rotations, which is mainly used in physics.

Unified formulation of the Hamilton-Jacobi problem for multisymplectic classical field theories

**Pedro Daniel Prieto-Martínez**

UPC, Spain
e-mail: peredaniel@ma4.upc.edu

**Abstract**

The geometric framework for the Hamilton-Jacobi theory developed in [1, 2] has been extended to multisymplectic first-order classical field theories in a recent work [3], where the Hamilton-Jacobi problem is stated for both the Lagrangian and the Hamiltonian formalisms of these theories. In this work we aim to give a unified formulation of this problem using the Lagrangian-Hamiltonian unified formalism, or Skinner-Rusk formulation, for field theories developed in [4]. The generalized and standard Hamilton-Jacobi problems are stated and characterized in several equivalent ways. Also, particular and complete solutions to the problems are defined, and we recover both the
Lagrangian and Hamiltonian solutions to the problem. The use of distributions in a suitable fiber bundle that represent the solutions to the field equations is the fundamental tool in this formulation, as it was in [3].

References


Reduction and projectability of higher-order field theories and mechanics

**Narciso Román-Roy** and **Jordi Gaset Rifá**

UPC, Spain
e-mail: nrr@ma4.upc.edu
e-mail: gaset.jordi@gmail.com

Abstract

There are some models in higher-order mechanics and classical field theories where, as a consequence of the singularity of the Lagrangian, the order of the Euler-Lagrange
equations is lower than expected (for instance, the Hilbert Lagrangian for the Einstein equations). A geometrical way of understanding this problem is considering the projectability of the higher-order Poincaré-Cartan form to lower-order jet bundles. We study the conditions for this projectability and their consequences, thus enlarging the results stated in some previous papers of M. Castrillón, M.E. Rosado, and J. Muñoz-Masqué.

References


Monotone Riemannian manifolds and minimal submanifolds

JUAN J. SALAMANCA

UNIVERSIDAD DE CÓRDOBA, SPAIN

e-mail: jjsalamanca@uco.es

Abstract

In this poster, I study some features of the Geometry at first order. Usually, geometrical properties of a Riemannian manifold are stated by curvature conditions. Here, our approach is different: by means of a natural first-order tensor field.

We define a new class of Riemannian manifolds, depending on a global behavior of this tensor field. Some of its more outstanding properties are highlighted. We can prove that a small enough set of any Riemannian manifold belongs to this family. Another
classical family of manifolds that fixes also in this class are the Cartan-Hadamard manifolds.

By considering minimal submanifolds we obtain interesting information of a Riemannian manifold. Our goal is to prove that, in the class of Riemannian manifolds stated, any minimal submanifold must be contained in a leaf of a distinguished foliation.

The power of the new techniques developed appears clearer when we focus our attention in two cases: the compact and the Cartan-Hadamard.

On one hand, we obtain that for any compact Riemannian manifold there exists an associated number in $(0,1)$ which provides information about the size of minimal submanifolds. For the round sphere, we compute that this number is a half. It is suggested if this fact can provide another characterization for the round sphere.

On the other hand, for a simply-connected Cartan-Hadamard manifold we discover two new features. First, we prove that there exist no compact minimal submanifold. The other feature resembles a maximum principle. It is known that, in $\mathbb{R}^n$, no minimal submanifold can attain a strict maximum point (seen locally as a graph). We prove that the same behavior holds for a Cartan-Hadamard manifold. Moreover, it does not happen in other manifolds, even requiring curvature boundedness hypothesis. Hence, failing its extension to another kind of manifolds.

References


Deformations of coisotropic submanifolds in abstract Jacobi manifolds

GIUSEPPE TORTORELLA

FLORENCE UNIVERSITY, ITALY
e-mail: alfonso.tortorella@math.unifi.it

Abstract

In our work [3], using the Atiyah algebroid and first order multi-differential calculus on non-trivial line bundles, we attach an $L_\infty$-algebra to any coisotropic submanifold
$S$ in an abstract (or Kirillov’s) Jacobi manifold. Our construction generalizes and unifies analogous constructions in [4] (symplectic case), [1] (Poisson case), [2] (locally conformal symplectic case). As a new special case, we attach an $L_\infty$-algebra to any coisotropic submanifold in a contact manifold, including Legendrian submanifolds. The $L_\infty$-algebra of a coisotropic submanifold $S$ governs the (formal) deformation problem of $S$.

References


Self-duality of quasi-Einstein metrics

XABIER VALLE REGUEIRO

UNIVERSIDADE DE SANTIAGO DE COMPOSTELA. SPAIN
E-mail: xabiervalle@gmail.com

Abstract

A pseudo-Riemannian manifold $(M, g)$ is quasi-Einstein if there is a smooth function $f : M \to \mathbb{R}$ satisfying the equation

$$\text{Hess}_f + \rho - \mu df \otimes df = \lambda g,$$

(1)

where $\rho$ is the Ricci tensor of $(M, g)$ and $\mu, \lambda \in \mathbb{R}$.

Einstein metrics ($f = \text{const.}$) and gradient Ricci solitons ($\mu = 0$) are quasi-Einstein but there are many other interesting cases for special values of the parameter $\mu \in \mathbb{R}$. 

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For instance, if $\mu = -\frac{1}{\dim M - 2}$, then $(M, g)$ is conformal to an Einstein metric and moreover, if $\mu = \frac{1}{m}$ for some positive integer $m$, then there exist Einstein warped products of the form $M \times \varphi F$, where $\dim F = m$ and the warping function $\varphi$ is determined by the potential function $f$.

Since self-dual Einstein metrics play a distinguished role in many geometrical situations, our purpose is to describe the local structure of self-dual quasi-Einstein metrics, extending to the neutral signature case previous results obtained in the Riemannian setting [3].

**Theorem 1.** Let $(M, g)$ be a four-dimensional manifold with metric $g$ of neutral signature and let $f$ be a smooth function satisfying (1).

1. If the level hypersurfaces of $f$ are non-degenerate (i.e., $||\nabla f||^2 \neq 0$), then $(M, g)$ is locally a warped product of the form $I \times \varphi F$, where $F$ is a space of constant curvature. Hence $(M, g)$ is locally conformally flat.

2. If the level hypersurfaces of $f$ are degenerate (i.e., $||\nabla f||^2 = 0$), then $(M, g)$ is locally the cotangent bundle $T^*\Sigma$ of a torsion-free affine surface $(\Sigma, D)$ equipped with a deformed Riemannian extension $g_{D, \Phi}$, where $\Phi$ is a symmetric $(0, 2)$-tensor field on $\Sigma$. Moreover the potential function is the pull-back $f = \pi^*h$ to $T^*\Sigma$ of a function $h : \Sigma \to \mathbb{R}$ satisfying the affine quasi-Einstein equation $\text{Hess}_h^D + \rho_{sym}^D - \mu dh \otimes dh = 0$.

The above result provides a procedure to build examples of self-dual quasi-Einstein metrics of neutral signature which are not locally conformally flat, in opposition to the Riemannian case [3, 4].

**References**


### Part VI
#### LIST OF PARTICIPANTS

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<tr>
<th>Name</th>
<th>Surname</th>
<th>Institution</th>
<th>E-Mail</th>
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<tbody>
<tr>
<td>Lígia Abrunheiro</td>
<td>CIDMA and University of Aveiro</td>
<td><a href="mailto:abrunheiroliligia@ua.pt">abrunheiroliligia@ua.pt</a></td>
<td></td>
</tr>
<tr>
<td>Daniele Angella</td>
<td>Centro di Ricerca Matematica “Ennio de Giorgi”, Pisa</td>
<td><a href="mailto:daniele.angella@sns.it">daniele.angella@sns.it</a></td>
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<tr>
<td>Paulo Antunes</td>
<td>University of Coimbra</td>
<td><a href="mailto:pantunes@mat.uc.pt">pantunes@mat.uc.pt</a></td>
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<tr>
<td>Manuel Asorey</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:asorey@unizar.es">asorey@unizar.es</a></td>
<td></td>
</tr>
<tr>
<td>Angel Ballesteros</td>
<td>Universidad de Burgos</td>
<td><a href="mailto:angelb@ubu.es">angelb@ubu.es</a></td>
<td></td>
</tr>
<tr>
<td>Jesús Fernando</td>
<td>Instituto de Estructura de la Materia, CSIC</td>
<td><a href="mailto:fbarbero@iem.cfmac.csic.es">fbarbero@iem.cfmac.csic.es</a></td>
<td></td>
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<tr>
<td>Miguel Brozos Vázquez</td>
<td>Universidade da Coruña</td>
<td><a href="mailto:mbrozos@udc.es">mbrozos@udc.es</a></td>
<td></td>
</tr>
<tr>
<td>Margarida Camarinha</td>
<td>University of Coimbra</td>
<td><a href="mailto:mmilsc@mat.uc.pt">mmilsc@mat.uc.pt</a></td>
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<td>José Cariñena</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:jfc@unizar.es">jfc@unizar.es</a></td>
<td></td>
</tr>
<tr>
<td>Roger Casals</td>
<td>ICMAT</td>
<td><a href="mailto:casals.roger@icmat.es">casals.roger@icmat.es</a></td>
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<tr>
<td>Raquel Caseiro</td>
<td>University of Coimbra</td>
<td><a href="mailto:raquel@mat.uc.pt">raquel@mat.uc.pt</a></td>
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<td>Pablo Miguel Chacón</td>
<td>Universidad de Salamanca</td>
<td><a href="mailto:pmchacon@usal.es">pmchacon@usal.es</a></td>
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<td>Jesús Clemente-Gallardo</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:jesus.clementegallardo@bifi.es">jesus.clementegallardo@bifi.es</a></td>
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<td>Manuel de León</td>
<td>ICMAT</td>
<td><a href="mailto:mdeleon@icmat.es">mdeleon@icmat.es</a></td>
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<td>Antonio De Nicola</td>
<td>University of Coimbra</td>
<td><a href="mailto:antontdenicola@gmail.com">antontdenicola@gmail.com</a></td>
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<tr>
<td>Stanislaw Ewert-Krzemieniewski</td>
<td>West Pomeranian University of Technology, School of Mathematics</td>
<td><a href="mailto:ewert@zut.edu.pl">ewert@zut.edu.pl</a></td>
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<td>Fernando Falceto</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:falceto@unizar.es">falceto@unizar.es</a></td>
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<tr>
<td>Marisa Fernández</td>
<td>Universidad del País Vasco</td>
<td><a href="mailto:marisa.fernandez@elu.es">marisa.fernandez@elu.es</a></td>
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<tr>
<td>José Fernández Núñez</td>
<td>Universidad de Oviedo</td>
<td><a href="mailto:nonius@umiovi.es">nonius@umiovi.es</a></td>
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<tr>
<td>Ana Cristina Ferreira</td>
<td>University of Minho</td>
<td><a href="mailto:anaferreira@math.uminho.pt">anaferreira@math.uminho.pt</a></td>
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<td>Pedro Luis García Pérez</td>
<td>Universidad de Salamanca y Real Academia de Ciencias</td>
<td><a href="mailto:pgarcia@usal.es">pgarcia@usal.es</a></td>
</tr>
<tr>
<td>22</td>
<td>Eduardo García Río</td>
<td>Universidade de Santiago de Compostela</td>
<td><a href="mailto:eduardo.garcia.rio@usc.es">eduardo.garcia.rio@usc.es</a></td>
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<tr>
<td>23</td>
<td>Jordi Gasset Rifá</td>
<td>Universitat Politècnica de Catalunya</td>
<td><a href="mailto:gasset.jordi@gmail.com">gasset.jordi@gmail.com</a></td>
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<tr>
<td>24</td>
<td>Sandra Gavino-Fernández</td>
<td>Universidade de Santiago de Compostela</td>
<td><a href="mailto:sandra.gavino@gmail.com">sandra.gavino@gmail.com</a></td>
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<tr>
<td>25</td>
<td>Simone Gutt</td>
<td>Università Libre de Bruxelle</td>
<td><a href="mailto:Simone.Gutt@ulb.ac.be">Simone.Gutt@ulb.ac.be</a></td>
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<td>26</td>
<td>David Iglesias</td>
<td>Universidad de La Laguna</td>
<td><a href="mailto:iglesiasponte@gmail.com">iglesiasponte@gmail.com</a></td>
</tr>
<tr>
<td>27</td>
<td>Madeleine Jotz Lean</td>
<td>University of Sheffield</td>
<td><a href="mailto:m.jotz-lean@sheffield.ac.uk">m.jotz-lean@sheffield.ac.uk</a></td>
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<td>28</td>
<td>Jorge Alberto Jover Galtier</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:jorge.jover@bifi.es">jorge.jover@bifi.es</a></td>
</tr>
<tr>
<td>29</td>
<td>George Kaimakamis</td>
<td>Hellenic Military Academy</td>
<td><a href="mailto:gmiamis@gmail.com">gmiamis@gmail.com</a></td>
</tr>
<tr>
<td>30</td>
<td>Alfonso Lanuza</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:alflaga@hotmail.com">alflaga@hotmail.com</a></td>
</tr>
<tr>
<td>31</td>
<td>Adela Latorre</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:adelalizar@gmail.com">adelalizar@gmail.com</a></td>
</tr>
<tr>
<td>32</td>
<td>Juan Margalef</td>
<td>UC3M-CSIC</td>
<td><a href="mailto:juan.margalef@uc3m.es">juan.margalef@uc3m.es</a></td>
</tr>
<tr>
<td>33</td>
<td>Giuseppe Marmo</td>
<td>Università di Napoli “Federico II”</td>
<td><a href="mailto:marmo@na.infn.it">marmo@na.infn.it</a></td>
</tr>
<tr>
<td>34</td>
<td>Juan Carlos Marrero</td>
<td>Universidad de La Laguna</td>
<td><a href="mailto:marrerojuanCarlos@gmail.com">marrerojuanCarlos@gmail.com</a></td>
</tr>
<tr>
<td>35</td>
<td>Verónica Martín</td>
<td>Universidad de Sevilla</td>
<td><a href="mailto:vmartin@unizar.es">vmartin@unizar.es</a></td>
</tr>
<tr>
<td>36</td>
<td>Eduardo Martínez</td>
<td>Universidad de Zaragoza</td>
<td><a href="mailto:emf@unizar.es">emf@unizar.es</a></td>
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<tr>
<td>37</td>
<td>Juan Mateos Guilarte</td>
<td>Universidad de Salamanca</td>
<td><a href="mailto:guilarte@usal.es">guilarte@usal.es</a></td>
</tr>
<tr>
<td>38</td>
<td>Filipe Mena</td>
<td>Universidade do Minho</td>
<td><a href="mailto:fmena@math.uminho.pt">fmena@math.uminho.pt</a></td>
</tr>
<tr>
<td>39</td>
<td>Valter Moretti</td>
<td>University of Trento</td>
<td><a href="mailto:moretti@science.unitn.it">moretti@science.unitn.it</a></td>
</tr>
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<td>40</td>
<td>Miguel Carlos Muñoz Lecanda</td>
<td>Universitat Politècnica de Catalunya</td>
<td><a href="mailto:matmcm@ma4.upc.edu">matmcm@ma4.upc.edu</a></td>
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<td>José Navarro Garmendia</td>
<td>Universidad de Extremadura</td>
<td><a href="mailto:navarroGarmendia@unex.es">navarroGarmendia@unex.es</a></td>
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<td>42</td>
<td>Joana Nunes da Costa</td>
<td>University of Coimbra</td>
<td><a href="mailto:jncosta@mat.uc.pt">jncosta@mat.uc.pt</a></td>
</tr>
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<td>43</td>
<td>Antonio Otal</td>
<td>Centro Universitario de la Defensa de Zaragoza</td>
<td><a href="mailto:aotal@unizar.es">aotal@unizar.es</a></td>
</tr>
<tr>
<td>44</td>
<td>Jesús Palacín</td>
<td>Universidad Pública de Navarra</td>
<td><a href="mailto:palacian@unavarra.es">palacian@unavarra.es</a></td>
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<td>Picken</td>
<td>Instituto Superior Técnico, Lisboa</td>
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<td>Universitat Politècnica de Catalunya</td>
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<td>Rodrigo Fernández</td>
<td>Academia Militar (Portugal)</td>
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<td>Université du Luxembourg</td>
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