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BOOKLET OF ABSTRACTS

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Contents

Minicourses

Contact Geometry and Thermodynamics

From TUE to THU 9:30

Alessandro Bravetti
CIMAT Guanajuato

In these lectures we present the geometric description of thermodynamics by means of contact geometry and contact Hamiltonian dynamics. These lectures being intended to both mathematicians and physicists, we will introduce all the relevant objects and keep the exposition as clear as possible for both audiences.

Variational Principles in Quantum Physics

From TUE to THU 12:30

Alberto Ibort
U. Carlos III - ICMAT

The "Lagrangian method", and its associated "Principle of Least Action", is arguably the most successful and at the same time profound idea in Physics. Its mathematical counterpart, starting with the classical "calculus of variations", is by no means less relevant and has had a deep impact in modern Topology and Geometry. However the transition from the application of the "Lagrangian method" in classical physics, in particular in the beautiful abstract form known today as Geometrical Mechanics (including the geometrical description of classical field theories), to quantum physics where Feynman's path integrals approach is ubiquitous (a cornerstone of modern physics), is far from being well understood.

The dynamical laws describing quantum systems have such a different character and structure from the classical ones that we may hardly relate them with their classical counterparts (along the years a number of contraptions under the name of "quantizations" have appeared trying to make sense of this disparity). In spite of all this, we want to point out that Julian Schwinger in his conceptualisation of the quantum theory of the electromagnetic field, introduced a quantum dynamical principle directly inspired in the Lagrangian method that he used with great success (he was awarded the Nobel Prize together with Feynman and Tomonaga because of this achievement).

Unfortunately Schwinger's ideas regarding the conceptual and mathematical structure of quantum systems are not as well known as we believe they deserve (the technical difficulties of the mathematical manipulations combined with a somehow obscure language could have contributed to that). It is a fact that most of the modern presentations of the quantum theory of fields are based on Feynman's approach (to the dismay of many mathematicians interested in understanding what are the problems facing modern theoretical physics).

It is true that other visions are available that have gained a lot of attention in the last decades; from the algebraic operator approach by Haag to the noncommutative geometry proposal by Connes, however we will prefer to turn out attention back to the turning point of the transposition of the "Lagrangian method" to quantum mechanics as devised by Schwinger and Feynman following the powerful inspiration provided by Dirac.

In these lectures we will try to convey the spirit of Schwinger's ideas by putting them in the solid mathematical framework provided by groupoid theory, a favourite of these Workshops. There we hope we will be able to show they fully display its elegance and deepness.

The first lecture will be devoted to review the "Lagrangian method" and to discuss Dirac's insight on how it could be used in quantum physics, insight that was instrumental in both Feynman's and Schwinger's theories. In the second lecture, Schwinger's algebra of measurements will be formulated from the point of view of groupoids and the basic notions and structures of the theory will be derived. The discussion on dynamics will be brought in the third lecture and finally, in the fourth lecture, the connection with Feynman's histories approach will be established and Schwinger's dynamical principle will be formulated.

Contents:

1. The Lagrangian in Quantum Mechanics: Dirac, Feynman and Schwinger's legacy.
2. Groupoids: an abstract kinematical setting for Quantum Mechanics.
3. Dynamics: histories and evolution, a dual approach.
4. Schwinger's variational principle.

Plenary Lectures

A geometric formulation of Ehrenfest molecular dynamics

TUE
11:30

Jesús Clemente-Gallardo

Universidad de Zaragoza

It is a very well known fact that the exact quantum description of heavy atoms and molecules is an impossible task and that suitable approximations are necessary to capture their main properties in an efficient way. One of the best known approximations corresponds to the hybrid quantum-classical model where the nuclei and inner electrons are treated as classical particles, the valence electrons are considered to be quantum, and the interaction of these quantum and classical particles is encoded in Ehrenfest equations. The geometric description of Quantum Mechanics can be used to build a tensorial version of that framework and prove that Ehrenfest equations are Hamiltonian with respect to a suitable hybrid symplectic form. This Hamiltonian nature allows us to define an invariant volume form for the phase space and, with it, it is possible to build a Statistical Mechanics to describe more general situations. In this talk, we will summarize the main properties of this approach and some interesting applications obtained by our group in the last years.

TUE
15:00

Topological insulators and superconductors

Elsa Prada

Universidad Autónoma de Madrid

Traditionally, we understand phases of matter such as liquid/solid or ferromagnetic/paramagnetic within Landau's paradigm, which is based on order parameters of a local nature. With the advent of the topology paradigm we have been able to discover new phases of matter that are realized in the so-called topological materials. These are described by topological invariants instead of local order parameters. Invariants take on discrete sets of values that describe order of a global nature. In this talk I will review general concepts of topological band theory and the bulk-boundary correspondence. I will apply these concepts first to topological insulators in one-, two- and three-dimensions, and then to topological superconductors in one- and two-dimensions. I will show specific paradigmatic materials within each category and the most celebrated condensed-matter experiments where their existence has been demonstrated. I will finish with important applications of their topologically-protected boundary states.

TUE
17:00

Solvability implies integrability

Janusz Grabowski

Institute of Mathematics, Polish Academy of Sciences

Integrability of a vector field means that you can find in an algorithmic way its flow in a given coordinate system. The existence of additional compatible geometric structures may play a relevant role and it allows us to introduce other concepts of integrability (e.g. Arnold-Liouville integrability).

Our aim is to develop the study of integrability in the absence of additional compatible structures, and more specifically the classical problem of integrability by quadratures, i.e. to study under what conditions you can determine the solutions by means of a finite number of algebraic operations (including inversion of functions) and quadratures of some functions.

We present a substantial generalisation of a classical result by Lie in this direction. Namely, we prove that all vector fields in a finite-dimensional transitive and solvable Lie algebra of vector fields on a manifold can be integrated by quadratures.

On the spacelike hypersurfaces with the same Riemannian and Lorentzian mean curvature

WED 11:30

Magdalena Caballero

Universidad de Córdoba

Spacelike hypersurfaces in the Lorentz-Minkowski space $\mathbb{L}^n$ can be endowed with another Riemannian metric, the one induced by the Euclidean space $\mathbb{R}^n$. Those hypersurfaces are locally the graph of a smooth function u satisfying $|Du| < 1$. If in addition they have the same mean curvature with respect to both metrics, they are the solutions to a certain partial differential equation, the $H_R = H_L$ hypersurface equation.

It is well known that the only surfaces that are simultaneously minimal in $\mathbb{R}^3$ and maximal in $\mathbb{L}^3$ are open pieces of helicoids and of spacelike planes, (O. Kobayashi 1983). Similar results have been obtained more recently for timelike surfaces (Kim-Lee-Yang 2009), and also for spacelike surfaces in the product spaces $\mathbb{S}^2 \times \mathbb{R}$ and $\mathbb{H}^2 \times \mathbb{R}$ (Kim-Koh-Shin-Yang 2009).

In this talk we consider the general case of spacelike hypersurfaces with the same mean curvature with respect to both metrics, paying special attention to the minimal and maximal case. Firstly in the Lorentz-Minkowski space, and afterwards in other ambient settings.

Discrete geometry of polygons and Hamiltonian structures

THU 11:30

Gloria Marí Beffa

University of Wisconsin-Madison

In this talk we will review how the discrete geometry of polygons in some parabolic manifolds helps us define Hamiltonian structures for some discrete evolutions, including well known integrable systems. We will use projective polygons as running example to illustrate the results, and discuss open problems. This is in part joint work with Jin Ping Wang (U of Kent at Canterbury) and Anna Calini (College of Charleston).

THU
15:00

Orbifold equivalence for simple, unimodal and bimodal singularities

Ana Ros Camacho

Mathematical Institute of Utrecht University

In this talk I will introduce orbifold equivalence, an equivalence relation between polynomials satisfying certain conditions ("potentials") which describe Landau-Ginzburg models. We will review how it relates the potentials associated to simple, (exceptional) unimodal and bimodal singularities, reproducing classical results like strange duality from the classification of singularities from Arnold. In addition, we will see that these equivalences seem to be controlled by Galois groups. Based on ongoing work with T. Kluck and G. Cornelissen and on joint work with R. Newton, I. Runkel et al.

THU
17:00

Harmonic maps and shift-invariant subspaces

Rui Pacheco

Universidade da Beira Interior, Covilhã

In the early 90s, G. Segal formulated the harmonicity equations for maps from surfaces into the unitary group in terms of the Grassmannian model of loop groups, in which harmonic maps (the non-linear sigma models of theoretical physics) correspond to certain families of shift-invariant subspaces of $L^2(S^1, \mathbb{C}^n)$. This point of view leads to a beautiful interplay between differential geometry and operator theory. We will present some new interesting results about harmonic maps from surfaces into Lie groups and their symmetric spaces that make explicit use of operator-theoretic methods. This is joint work in progress with Alexandru Aleman (University of Lund) and John C. Wood (University of Leeds).

Quantum Boundary Conditions

FRI 9:30

Giancarlo Garnero

Università degli Studi di Bari Aldo Moro

Boundary conditions are ubiquitous in every area of physics. The analysis of a physical system, indeed, usually discriminates the behaviour of the bulk from the surrounding environment. In this sense, boundary conditions are a crucial ingredient, interpreting the interaction between confined systems and the environment.

In this talk I will discuss how quantum boundary conditions emerge in the description of bounded non relativistic quantum systems. In particular, I am going to discuss the case of a quantum particle confined into a cavity. I will present different examples and dynamical applications, underlying the relation between the physical and geometrical aspects of the problem.

Noncommutative gauge theories through twist deformation quantization

FRI 12:00

Chiara Pagani

Università del Piemonte Orientale

In noncommutative geometry principal bundles consist of algebra extensions that satisfy the condition to be Hopf-Galois. In this algebraic setting, quantum groups and their (co)actions play a central role in the description of symmetries of noncommutative spaces.

In this seminar we describe a general theory of Drinfeld twist deformation quantization of Hopf-Galois extensions [Aschieri-Bieliavsky-Pagani-Schenkel, 2017] and present recent results on the study of the group of gauge transformations of a noncommutative bundle [Aschieri-Landi-Pagani, arXiv:1806.01841]. We illustrate the general theory through examples, focusing on instantons on quantum spheres.

Contributed Talks

Prescribing curvature for curves in Lorentz-Minkowski plane

TUE 10:30

Ildefonso Castro
Universidad de Jaén

Motivated by a problem proposed by David A. Singer in 1999 and by the classical Euler elastic curves, the aim of this talk is to study spacelike and timelike curves in Lorentz-Minkowski plane $\mathbb{L}^2$ with prescribed curvature. Specifically, we try to determine those curves $\gamma = (x, y)$ in $\mathbb{L}^2$ whose curvature κ depends on some given function $\kappa = \kappa(x, y)$. Concretely, we study (cf. [Castro-Castro Infantes-Castro Infantes, 2018] and [Castro-Castro Infantes-Castro Infantes, 2018]) spacelike and timelike curves whose curvature is expressed in terms of the Lorentzian pseudodistance to fixed geodesics (of different causality) or to a fixed point.

From a geometric-analytic point of view, we deal with the following problem: Given a unit-speed parametrization of a spacelike or timelike curve $\gamma = (x, y)$ in $\mathbb{L}^2 := (\mathbb{R}^2, g = -dx^2 + dy^2)$, we prescribe the curvature with some of the following extrinsic conditions:

(i) $\kappa = \kappa(y)$ or $\kappa = \kappa(x)$,

(ii) $\kappa = \kappa(v)$, where $v := y - x$,

(iii) $\kappa = \kappa(\rho)$, where $\rho := \sqrt{|g(\gamma, \gamma)|} = \sqrt{|-x^2 + y^2|} \geq 0$.

In this way, we get a complete description of the spacelike and timelike elastic curves in $\mathbb{L}^2$ and provide the Lorentzian versions of catenaries and grim-reaper curves. We also find out several new families of Lorentzian spacelike and timelike spirals. In addition, we provide uniqueness results for the generatrix curve of the Enneper's surface of second kind and for Lorentzian versions of some well known curves in the Euclidean setting, like the Bernoulli lemniscate, the cardioid, the sinusoidal spirals and some non-degenerate conics.

TUE
16:00

Jacobi multipliers and nonholonomic Lagrangian systems

Patricia Santos

University of Coimbra

We extended our previous work [Cariñena-Santos, 2016] that establish the relation between Jacobi multipliers (see e.g.[Cariñena-de Lucas-Rañada, 2015] and references therein) and Hamel's formalism [Papastavridis, 2002], to more general cases where the configuration space is not the Euclidian space. Specifically, several results and examples of nonholonomic Lagrangian systems on Riemannian manifolds are given.

TUE
18:00

Genus Integration, Abelianization and Extended Monodromy

Rui Loja Fernandes

University of Illinois at Urbana-Champaign

Given a Lie algebroid we discuss the existence of an abelian integration of its abelianization. We show that the obstructions are given by the so-called extended monodromy groups introduced recently. We also show that the abelianization can be obtained by a path-space construction, similar to the Weinstein groupoid, but where the underlying homotopies are now supported in surfaces with arbitrary genus, i.e., instead of A-homotopies one considers A-homologies. This talk is based on joint work with Ivan Contreras (Amherst College).

Lorentzian Poisson homogeneous spaces

WED
10:30

Ángel Ballesteros

Universidad de Burgos

Poisson homogeneous spaces (M, π) of a Poisson–Lie group (G, Π) are introduced, where M is given by $M = G/H$ and H is a given isotropy subgroup $H \subset G$. If $(\mathfrak{g}, \delta)$ is the Lie bialgebra associated to (G, Π), the characterization of Poisson homogeneous spaces (hereafter PHS) under (G, Π) is given in terms of the coisotropy condition for the cocommutator δ, which means that $\delta(\mathfrak{h}) \subset \mathfrak{h} \wedge \mathfrak{g}$, where $\mathfrak{h} = \mathrm{Lie}(H)$. The particular case when $\delta(\mathfrak{h}) \subset \mathfrak{h} \wedge \mathfrak{h}$ identifies the Poisson subgroup cases, which are less numerous but can be more easily promoted to quantum homogeneous spaces (see [Drinfel'd, 1993, Reyman, 1994, Ballesteros-Meusburger-Naranjo, 2017] and references therein).

In this contribution we present the explicit construction of some PHS on Lorentzian spacetimes. In particular, all PHS for the AdS group in (1+1) dimensions are studied. In (2+1) dimensions, Minkowski PHS coming from Drinfel'd double structures of the (2+1) Poincaré Lie algebra are systematically constructed [Ballesteros-Gutiérrez-Sagredo-Herranz, 2018]. Finally, a PHS for the (3+1) dimensional AdS group with respect to the so-called κ-Poisson-Lie structure is explicitly given, and its Minkowskian limit is obtain in the vanishing cosmological constant limit [Ballesteros-Gutiérrez-Sagredo-Herranz, 2018].

Finally, we will comment on the physical relevance of Lorentzian PHS as semiclassical counterparts of quantum homogeneous spaces. In this context, the Poisson homogeneous structure π on the classical Lorentzian spacetime M would provide a semiclassical signature of the noncommutativity between the spacetime coordinates that would be one of the possible footprints of Quantum Gravity effects at the Planck scale.

THU
10:30

Quantum Control on the Boundary

Juan José Pérez-Pardo

University Carlos III (Madrid)

Schroedinger equation is a linear evolution equation. The problem of controlling a finite dimensional quantum system is therefore a well understood problem where one can apply the classical theory of control. However, applying such ideas to the infinite dimensional setting is far from being straightforward. For instance, one immediately encounters difficulties with the definition of the dynamical Lie algebra due to the appearance of unbounded operators. In spite of the technical difficulties, the latter bring also new and interesting possibilities to the theory of quantum control. We will introduce notions of controllability suited for the infinite-dimensional situation and discuss how one can control the state of a system by means of changing its boundary conditions.

THU
16:00

Solutions of the Laplacian flow and coflow of a locally conformal parallel G_2-structure

Raquel Villacampa

Centro Universitario de la Defensa, Zaragoza

The development of flows in Riemannian geometry has been mainly motivated by the study of the Ricci flow. However, the same techniques are also useful in the study of flows involving other geometrical structures, like for example, the Kähler Ricci flow. Concerning flows on G_2-manifolds, for any closed G_2-structure σ_0 on a manifold M, Bryant (Proceedings of Gökova Geometry-Topology Conference 2005, 2006) introduced a natural flow, the so-called *Laplacian flow*, given by

$$\begin{cases} \frac{d}{dt}\sigma(t) = \Delta_t \sigma(t), \\ \sigma(0) = \sigma_0, \quad d\sigma(t) = 0, \end{cases}$$

where Δ_t is the Hodge Laplacian operator of the metric determined by $\sigma(t)$. The short time existence and uniqueness of solution for the Laplacian flow of any closed G_2-structure, on a compact manifold M, has been proved by Bryant and Xu in the unpublished paper arxiv:1101.2004[math.DG].

Karigiannis, McKay and Tsui (Diff. Geom. Appl. 2012) introduced the *Laplacian coflow*. In this case the initial G_2-form is claimed to be coclosed, i.e. $d * \sigma_0 = 0$. Up to now, short time existence of solution of the coflow is not known. Assuming short time existence and uniqueness of solution,

the authors show that the condition of the initial G_2-form σ_0 to be coclosed (equiv. ψ_0 closed) is preserved along the flow.

Here we are concerned with studying the Laplacian flow, resp. coflow, of an LCP G_2-structure on a manifold M defined as:

$$\frac{d}{dt}\sigma(t) = \Delta_t \sigma(t), \sigma(0) = \sigma_0$$
$$d\sigma(t) = 3\,\tau(t) \wedge \sigma(t), d *_t \sigma(t) = 4\,\tau(t) \wedge *_t\sigma(t).$$

$$\frac{d}{dt}\psi(t) = -\Delta_t \psi(t), \psi(0) = \psi_0,$$
$$d\psi(t) = 4\,\tau(t) \wedge \psi(t), d *_t \psi(t) = 3\,\tau(t) \wedge *_t\psi(t).$$

The first examples of long time solutions of these flows are given. Our examples are one-parameter families of Locally Conformal Parallel G_2-structures on solvable Lie groups. We start finding solutions for the Laplacian flow and the found solutions are used to construct long time solutions to the Laplacian coflow starting from a Locally Conformal Parallel structure. These results can be found in the preprint available in arxiv:1711.08644[math.DG].

Contact Dual Pairs

THU 18:00

Alfonso Giuseppe Tortorella

KU Leuven

In this work [Blaga-Salazar-Tortorella-Vizman, 2018] we investigate the notions of duality and dual pairs in Jacobi geometry [Crainic-Salazar, 2015]. We introduce a contact dual pair as a pair of Jacobi bundle maps defined on the same (generically non-coorientable) contact manifold and satisfying a certain orthogonality condition. The standard example is formed by the source and the target maps of a contact groupoid. Among various properties, we investigate the relation existing between symplectic dual pairs [Weinstein, 1983] and contact dual pairs via symplectization. Our main result is the proof of the characteristic leaf correspondence theorem for contact dual pairs. Indeed there is a one-to-one correspondence between the characteristic (symplectic or contact) leaves of the two Jacobi manifolds forming the legs of a contact dual pair with connected fibers. Finally we apply these results to the context of reduction theory. Indeed we prove that any free and proper contact groupoid action gives rise to the contact dual pair formed by the associated moment map and the projection on the orbit space. Consequently the characteristic leaf correspondence yields a new insight into the contact reduction method first introduced by Zambon and Zhu [Zambon-Zhu, 2006].

FRI 11:30

Gravitational Waves: some Geometric Properties

Anna Maria Candela
Università degli Studi di Bari Aldo Moro

Since 1974, many times indirect proofs of the existence of gravitational waves have been given but only in September 2015 physicists gave the official announcement that gravitational waves exist. Anyway, from a mathematical point of view, they have always been "real objects" and their geometric properties such as geodesic connectedness and geodesic completeness have been investigated. These results are in joint works with Rossella Bartolo, José Luis Flores, Alfonso Romero and Miguel Sánchez.

Posters

Bi-slant Submanifolds of Para Hermitian Manifolds

Pablo Alegre

Universidad Pablo de Olavide, Sevilla

In [Chen, 1990], B.-Y. Chen introduced slant submanifolds of an almost Hermitian manifold, as those submanifolds for which the angle θ between JX and the tangent space is constant, for any tangent vector field X. They play an intermediate role between complex submanifolds ($\theta = 0$) and totally real ones ($\theta = \pi/2$). Since then, the study of slant submanifolds has produced an incredible amount of results and examples. Moreover, some generalizations of them have also been defined, such as semi-slant, bi-slant or generic submanifolds.

On the other hand, many authors have studied slant submanifolds in different environments: Sasakian manifolds, almost product manifolds. The study of slant submanifolds in a semi-Riemannian manifold was also initiated: Lorentzian complex space forms, neutral Kaehler manifolds, neutral almost contact pseudo-metric manifolds, LP-contact manifolds, Lorentzian Sasakian and para Sasakian manifolds.

In [Alegre-Carriazo, 2017], we introduced slant submanifolds of para Hermitian manifolds. These ambient spaces have a rich structure, similar to that of almost Hermitian ones, but also with very interesting differences. Now we continue intruducing bi-slant submanifolds of Para Hermitian Manifolds.

On L_∞-bialgebroids and Courant algebroids

Paulo Antunes
University of Coimbra

We show that Courant algebroids corresponds to new constructions of (curved) L_∞-algebroids and generalizations of L_∞-bialgebroids.

$*$-slant submanifolds

Joaquín Barrera López
University of Sevilla

It was proven by A. Ros and F. Urbano that if M^m is a Lagrangian submanifold of $\mathbb{C}^n$, with mean curvature vector H and scalar curvature τ, then $|H|^2 \geq \frac{2(m+2)}{m^2(m-1)}\tau$, with equality if and only if M is either totally geodesic or a (piece of a) Whitney sphere. Moreover, it was proven that M^m satisfies the equality case at every point, if and only if its second fundamental form σ is given by

$$\sigma(X,Y) = \frac{m}{m+2}\{g(X,Y)H + g(JX,H)JY + g(JY,H)JX\}, \tag{1}$$

for any tangent vector fields X, Y.

Later, D. E. Blair and A. Carriazo established an analogue of the above result for anti-invariant submanifolds in $\mathbb{R}^{2m+1}$ with its standard Sasakian structure and they gave a characterization by using the second fundamental form, similar to the equation (1) given by A. Ros and F. Urbano.

We introduce the notion of $*$-slant submanifold as that slant submanifold whose second fundamental form satisfies the equality case of an inequality between its mean curvature and its scalar curvature of a generalized Sasakian space form $\widetilde{M}^{2m+1}(f_1, f_2, f_3)$ whose structure is (α, β) trans-Sasakian. In addition to that, we give several interesting examples about these submanifolds.

These submanifolds generalize the *$*$-Legendrian submanifolds* of a Sasakian space form $\widetilde{M}^{2m+1}(c)$, which were studied by G. Pitiş. They are invariant submanifolds, of dimension m, whose second fundamental form satisfies the equality case in a similar inequality between τ and H.

Finally, we obtain an equality for the Ricci curvature of a $*$-slant submanifold involving its mean curvature in a generalized Sasakian space form $\widetilde{M}^{2m+1}(f_1, f_2, f_3)$ whose structure is (α, β) trans-Sasakian.

A note on Haantjes tensors

Raquel Caseiro
University of Coimbra

Haantjes tensors are $(1,1)$-tensors that have integrable generalized eigenvector distributions. They generalize Nijenhuis tensors and are used in the study of separable integrable systems. In this work, we relate Haantjes tensors with Frolicher-Nijenhuis bracket and prove that combinations of functions and commuting compatible Nijenhuis tensors are Haantjes tensors. In particular, we obtain that multiply twisted products of Nijenhuis tensors are Haantjes tensors.

Quantum Hall effect and Macdonald polynomials

Laura Colmenarejo
York University

Jack polynomials have many applications in physics, in particular in statistical physics and quantum physics, due to their relation to the many-body problem. In particular, fractional quantum Hall states of particles in the lowest Landau levels are described by such polynomials. In that context, some properties, called clustering properties, are highly relevant and means that the Jack polynomial vanishes when s distinct clusters of $k+1$ equal variables are formed. Coming from theoretical physics, the study of these properties raises very interesting problems in combinatorics and representation theory of the affine Hecke algebras. More precisely, the problem is studied in the realm of Macdonald polynomials which form a (q,t)-deformation of the Jack polynomials. Instead of stating the results in terms of clustering properties, we prefer to state them in terms of factorizations. Indeed, clustering properties are shown to be equivalent to very elegant formulas involving factorizations of Macdonald polynomials.

Starting with a brief account on the physics motivations, we would like to present some special cases of specializations for which the factorizations present very interesting properties. As a consequence of the singularity of some quasistaircase Macdonald polynomials proved in [Jolicoeur-Luque, 2011], we deduce factorizations from the results of [Feigen et al, 2003] and we illustrate our results by proving a conjecture stated by Bernevig and Haldane [Bernevig-Haldane, 2008].

Applications of the two-parameter invariant function $\bar{\psi}^0_{\mathfrak{g}}(\alpha, \beta)$ to filiform Lie algebras

José M. Escobar

Universidad de Sevilla

Continuing with the research followed in previous papers by Novotný and Hrivnák, and by ourselves in [Escobar-Núñez-Pérez-Fernández 2018], we introduce in this communication a new two-parameter invariant function of algebras, denoted by $\bar{\psi}^0_{\mathfrak{g}}(\alpha, \beta)$, show its main properties and compute its value in the particular case of filiform Lie algebras, for certain values of the parameters α and β.

Metrics on Whitney sum of sphere bundles over a submanifold induced from a g natural one

Stanislaw Ewert-Krzemieniewski

West Pomeranian University of Technology

The geometry of the tangent sphere bundle over a Riemannian manifold (N, g), with nondegenerate g-natural metric, has been studied by many authors.

Let M be a manifold isometrically immersed into a Riemannian manifold (N, g) and let (TN, G) be the tangent bundle of N, endowed with a g-natural, possibly degenerate, metric G. We investigate the curvature properties of the direct sum of two sphere bundles $TS_{r_1} \oplus TS_{r_2}$ over the submanifold M. The first one is a bundle of vectors of constant length r_1 tangent to M, while the second one consists of vectors normal to M and of constant length r_2. The metric on $TS_{r_1} \oplus TS_{r_2}$ is a nondegenerate g-natural one induced from the metric G.

Type D conformal initial data

Alfonso García-Parrado
Charles University, Prague

We construct inital data for the vacuum conformal Friedrich equations in 4-dimensions such that the data development admits a Weyl tensor of Petrov type D. Our starting point for this task is a vacuum initial data set for the Einstein field equations and we carry out a conformal rescaling (conformal compactification) of these vacuum data. This gives rise to initial data for the (vacuum) conformal equations. When will the data development under the conformal equations be a conformal extension of a type D solution? In this work we answer this question following techniques similar to those of [García-Parrado, 2016]. A number of initial data sets for the conformal equations are explored. Recall that vacuum type D solutions of the Einstein equations contain cases as important as the Schwarzschild and the Kerr solution.

Differential invariants of Fedosov structures

Adrián Gordillo-Merino
Universidad de Extremadura

Local differential invariants of Fedosov structures are studied, following the style of the study begun in [Gelfand-Retakh-Shubin, 1998]. We present *normal developments*, in a similar manner to [Gordillo-Navarro, 2017] or [Gordillo-Navarro-Sancho, 2010]. These are used to prove that the space of differential invariants can be identified with a certain space of smooth functions invariant under the action of the symplectic group.

Then, this result allows us to provide a description of natural tensors of order r associated with Fedosov structures, and we can also state and prove a pair of simple corollaries:

1. There is no differential scalar invariant of a Fedosov structure which is linear on the second derivatives of the 2-form.

2. On a Fedosov manifold, the only natural 2-tensors which are linear on the second derivatives of the 2-form are the constant multiples of the Ricci tensor.

Material distributions

Víctor M. Jiménez

Universidad Autónoma de Madrid - ICMAT

A groupoid, called *material groupoid*, is associated in a natural way over a general non uniform body (see [Epstein-deLeon, 2016]). Due to the lack of differentiability properties of the material groupoid (it is not, generally, a Lie groupoid), we need to introduce new tools in order to study the general case. Is in this context where the *material distributions* are introduced. As a first result, the material distributions and its associated singular foliations result in a rigorous and unique subdivision of the material body into strictly smoothly uniform components (see, for instance [Jimenez-Epstein-deLeon, 2018]). Thus, the constitutive law induces a unique partition of the body into smoothly uniform sub-bodies, laminates, filaments and isolated points.

Einstein's equation on a Weyl geometry

José Navarro

Universidad de Extremadura

A *Weyl geometry* is a triple $(X, \langle g\rangle, \nabla)$, where X is a smooth manifold, $\langle g\rangle$ is a conformal semiriemannian structure, and ∇ is a compatible symmetric linear connection; that is to say, a symmetric linear connection such that, for any representative g of the conformal structure, there exists a 1-form α such that $\nabla g = \alpha \otimes g$.

Following the ideas presented in [Navarro, 2013], we study natural 2-tensors associated to a Weyl structure. We pay special attention to those tensors that are *divergence-free*, and discuss their relation with a relativistic field equation on a Weyl spacetime ([Navarro-Sancho, 2008], [Navarro-Sancho, 2012]).

In particular, we prove that the existence of a divergence-free, natural 2-tensor that is *symmetric* implies the local triviality of the Weyl structure; that is to say, the existence of a representative g on the conformal structure such that ∇ is the Levi-Civita connection of g.

ESQPTs and thermal phase transition in the Dicke model

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It is well known from the 70s that the Dicke model undergoes a thermal phase transition [Duncan, 1974]. Also, recently it has been found that this model displays a Quantum Phase Transition (QPT) as well as an Excited State Quantum Phase Transition (ESQPT) [Pérez Fernández et al, 2011]. We study the thermodynamic of the full version of the Dicke model and we look for joint features between the thermal phase transition and the ESQPT. We find a common order parameter for both transitions [Pérez Fernández-Relaño, 2017].

High-order geometric integrators for nonholonomic systems

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In this talk I present a newly obtained family of geometric, arbitrarily high-order partitioned Runge-Kutta integrators for nonholonomic systems, both on vector spaces and Lie groups. These methods differ from those of [Cortés-Martínez, 2001] in that we do not require that a discretisation of the constraint be provided, and contrary to L. Jay's SPARK integrators in [Jay, 2009], we do not require extraneous combinations of constraint evaluations. Our methods preserve the continuous constraint exactly and can be seen to extend those of [de León-Martín de Diego-Santamaría, 2004].

Curvature Effects in Flocking Dynamics: A Cucker-Smale type model on Riemannian Manifolds

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The dynamics of the Cucker-Smale model facilitate the flocking of a group of particles in disordered motion into a coordinated one where all particle move parallelly with the center of mass. It illustrates not only the flocking of animals but also the general emergence of collective behaviour in a wide range of subjects. While their work already received much attention over the last decade, those efforts focused on particles moving in a Euclidean space.

We generalise the model to complete Riemannian manifolds and establish theorems about the convergence of the particles to a flocked state. On a Riemannian manifold the notion of parallelism is intimately related to curvature and the geometry constrains the final flocked state into specific patterns. Next to this interesting phenomenology, our work also is a contribution towards the flocking realizability problem as described in [Chi-Choi-Ha, 2014]. Given a manifold and a group of particles, this problem asks for a dynamical system that leads to a collective movement as a flock at least asymptotically. This project is joint work with Seung-Yeal Ha and Doheon Kim from Seoul National University.

Persistent Homology and Physical Applications

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Topological data analysis is an emerging field which seeks to discover the underlying space of a data sample. Due to the omnipresence of data in current science and society, it has been applied in numerous fields. In physics, the possible outcome of an experiment is constrained to its configuration space which is usually a differentiable manifold.
In particular, one of the most important qualitative features of a manifolds are its Betty numbers. They describe in a simple way its global structure and there exist plenty of analytical strategies to compute them. Despite this, problems arises when the geometric object is too complex or there are not concrete analytical methods for a specific case. In the beginning of this century a change of paradigm happened with the discovery of persistent homology.
This allows us to deduce the Betti numbers of a manifold from a dense enough

finite point sample of it. Then, this strategy has a constructive nature and can be solved by computers. This gives persistent homology an interesting double utility: it can helps to understand a rather complicated geometric object computing its Betti numbers and facilitating a posterior analytical study or it can be used to actually compare the topological features of your analytical model with finite samples obtained from a real world experiment. Our aim is to provide a review of this techniques and how they have been applied in recent years to the Cosmic Web [Cirafici, 2016], to the string vacua [Donato et al, 2016] and to the analysis of phase transitions [Pranav et al, 2017]. In addition, we will analyse new possibilities from both, the physical and the topological point of view.

Some Myers-Type Theorems for Transverse Ricci Solitons on Sasaki Manifolds

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An important problem in Riemannian geometry is to investigate the relation between topology and geometric structure on Riemannian manifolds. The celebrated theorem of S. B. Myers (1941) guarantees the compactness of a complete Riemannian manifold under some positive lower bound on the Ricci curvature. This theorem may be considered as a topological obstruction for a complete Riemannian manifold to have a positive lower bound on the Ricci curvature. On the other hand, J. Lohkamp (1994) proved that in dimension at least three, any manifold admits a complete Riemannian metric of negative Ricci curvature. Hence, in dimension at least three, there are no topological obstructions to the existence of a complete Riemannian metric of negative Ricci curvature. To give an interesting compactness criterion for complete Riemannian manifolds is one of the most important problems in Riemannian geometry, and the Myers theorem has been widely generalized in various directions by many authors.

The aim of my poster is to discuss the compactness of transverse Ricci solitons. The notion of Ricci solitons were introduced by R. Hamilton in 1982 and are natural generalizations of Einstein manifolds. They correspond to self-similar solutions to the Ricci flow and often arise as singularity models of the flow. The importance of Ricci solitons was demonstrated by G. Perelman, where Ricci solitons played crucial roles in his affirmative resolution of the Poincaré conjecture.

In my poster, I would like to generalize the notion of Ricci solitons to the case of sub-Riemann geometry, and define the notion of transverse Ricci solitons for Riemannian foliations. After we have reviewed basic facts on Myers theorems for Ricci solitons, we shall establish some new Myers theorems for transverse Ricci solitons on Sasaki manifolds. Our results may be regarded as natural generalizations of the Myers theorems due to W. Ambrose (1957), J. Cheeger, M. Gromov, and M. Taylor (1982), M. Fernández-López and E. García-Río (2008), M. Limoncu (2010 and 2012), Z. Qian (1997), the author (2016 and 2018), and G. Wei and W. Wylie (2009).

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