XVIII International Young Researchers Workshop in Geometry, Dynamics and Field theory

Programme and abstracts

February 21–23, 2024

Faculty of Physics, University of Warsaw, Poland

fuw.edu.pl/KMMF/18ywgmc

Schedule

Wednesday, February 21

- Registration and opening (08:30 – 09:00)
- **María Amelia Salazar** (09:00 – 10:30)
  Course: *Van est maps: the relation between the cohomology of Lie groups and the cohomology of Lie algebras* I

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- **Leonardo Colombo** (11:00 – 12:30)
  Course: *Safety-guarantees with data-driven controls based on Gaussian processes for quadrotors UAVs and multi-agent systems* I
- **Omayra Yago** (12:30 – 13:00)
  Talk: *Safe online learning-based control for an aerial robot with manipulator arms*

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- **Damiano Rigo** (14:00 – 14:30)
  Talk: *Geometric methods for designing optimal filters on Lie groups*
- **Mats Vermeeren** (14:30 – 16:00)
  Course: *Hamiltonian and Lagrangian perspectives on integrable systems* I

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- **Rubén Izquierdo** (16:30 – 16:40)
  Gong: *Coisotropic reduction in different phase spaces*
- **Samuel Luque Astorga** (16:40 – 16:50)
  Gong: *A Review on Reduction and Reconstruction of Dynamics in Symplectic Geometry*
- **Arnoldo Guerra IV** (16:50 – 17:00)
  Gong: *Canonical lifts in Multisymplectic De Donder–Weyl Hamiltonian Field Theories*
- **Federico Vesentini** (17:00 – 17:10)
  Gong: *A Brownian–Markov Stochastic Model for Cart-like Wheeled Mobile Robots*
- **Pablo Nicolás** (17:10 – 17:20)
  Gong: *Poisson cohomology of b^m-Poisson manifolds*

- **Óscar Carballal** (17:20 – 17:30)
  Gong: *A representation theory approach to Lie–Hamilton systems based on* $\mathfrak{sp}(4,\mathbb{R})$ *and applications*

- **Jacob Goodman** (17:30 – 18:00)
  Talk: *Reduction by Symmetry and Optimal Control in Riemannian Homogeneous Spaces*

Thursday, February 22

- **Leonardo Colombo** (09:00 – 10:30)
  Course: *Safety-guarantees with data-driven controls based on Gaussian processes for quadrotors UAVs and multi-agent systems* II

- Poster session (10:30 – 11:30)

- **Mats Vermeeren** (11:30 – 12:30)
  Course: *Hamiltonian and Lagrangian perspectives on integrable systems* II

- **Efstratios Stratoglou** (12:30 – 13:00)
  Talk: *Virtual constraints on Lie groups*

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- **Jagna Wiśniewska** (14:00 – 14:30)
  Talk: *Floer theory in the analysis of Hamiltonian systems*

- **María Amelia Salazar** (14:30 – 16:00)
  Course: *Van est maps: the relation between the cohomology of Lie groups and the cohomology of Lie algebras* II

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- **Leonardo Colombo** (16:30 – 17:30)
  Course: *Safety-guarantees with data-driven controls based on Gaussian processes for quadrotors UAVs and multi-agent systems* III

- **Markus Schlarb** (17:30 – 18:00)
  Talk: *Rolling Reductive Homogeneous Spaces*

Friday, February 23

- **María Amelia Salazar** (09:00 – 10:00)
  Course: *Van est maps: the relation between the cohomology of Lie groups and the cohomology of Lie algebras* III

- **Mariana Costa** (10:00 – 10:30)
  Talk: *Integrable and chaotic generalizations of the rolling of a convex body without slipping on a plane*

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- **Mats Vermeeren** (11:00 – 12:30)
  Course: *Hamiltonian and Lagrangian perspectives on integrable systems* III
- **Asier López-Gordón** (12:30 – 13:00)
  Talk: *On the stability of contact Hamiltonian systems*
- Closing (13:00 – 13:30)

Courses

Van est maps: the relation between the cohomology of Lie groups and the cohomology of Lie algebras

María Amelia Salazar
(Universidade Federal Fluminense, Brazil)

The classical Van Est theory relates the smooth cohomology of Lie groups with the cohomology of the associated Lie algebra, or its relative versions. Some aspects of this theory generalize to Lie groupoids and their Lie algebroids. We will revisit the van Est theory using the Perturbation Lemma from homological algebra. Using this technique, we will obtain precise results for the van Est differentiation and integrations maps at the level of cochains. Specifically, we will construct homotopy inverses to the van Est differentiation maps that are right inverses at the cochain level.

Safety-guarantees with data-driven controls based on Gaussian processes for quadrotors UAVs and multi-agent systems

Leonardo Colombo
(Centre for Automation and Robotics CSIC-UPM, Spain)

The modeling and identification of dynamical systems is of great importance in a large range of domains including physics, engineering, biology, and chemistry. Applications range from model-based control of autonomous systems and the perception of dynamical objects to the understanding of complex reaction processes in chemical reactors. Whereas classical models of physical systems are typically based on first principles, there is a recent shift to more data-driven modeling of complex dynamics to capture more details in a more efficient manner. However, this paradigmatic shift introduces new questions regarding the efficiency, interpretability, and physical correctness of the model, that is, the learned model respects physical principles such as preservation of the constraints, volume, and energy. Including physical principles in a data-driven approach is beneficial in several ways: the models are meaningful as they respect the postulates of physics, come with increased interpretability, and can be more data-efficient as the satisfaction of physical axioms, which results in a meaningful inductive bias for the outputs of the model.

Data-driven models require only minimal prior knowledge to model complex dynamics, and they are not limited to a finite set of parameters, as happens with typical system identification methods. Probably, the most widely studied data-driven technique for modeling dynamical systems, together with Gaussian Mixture Models and Hidden Markov Models, is the theory of Gaussian Processes (GPs) due to its characteristic of describing the dynamics with small training datasets and high probabilities. This technique is based on Bayesian methods. The Bayesian methodology is a probabilistic construction allowing the combination of new information with existent information: by using Bayes' theorem, current knowledge is combined with the information of new data to improve the knowledge. An alternative to the Bayesian approach for learning-based modeling of dynamical systems is the use of Neural Networks (NNs) and Reinforce Learning (RL).

In recent years, there have been advances in the use of RL to learn dynamical systems and design controllers driven by data. Nevertheless, for complex nonlinear dynamics such as the coordinated motion of multiple mechanical systems, the training with RL does not provide an uncertainty quantification of the prediction outputs and can have difficulty generalizing from sparse data. For this reason, in this mini-course, we focus on modeling with Gaussian Process Regression (GPR), a supervised learning technique based on GPs, so that the online learning provides a quantified uncertainty of the prediction and also provides training and update of predictions in real-time in comparison with classical NNs and RL. This uncertainty calculation is very valuable because it provides probabilistic safety guarantees for the system, that is, it provides probabilistic error bounds for the predictions using GPs that can be used, for instance, as ultimate bounds for the tracking error of autonomous vehicles to reach a desired trajectory which is the main application we will explore in the mini course.

Hamiltonian and Lagrangian perspectives on integrable systems

Mats Vermeeren
(Loughborough University, United Kingdom)

Classical integrable systems are traditionally formulated in terms of Hamiltonian mechanics. We will review this perspective, with the Liouville-Arnold theorem as a key result, and contrast it with a much more recent approach to integrable systems based on Lagrangian mechanics. The central objects in this approach are known as "Lagrangian multiforms" or "pluri-Lagrangian systems". After developing both perspectives for integrable ODEs, we will briefly discuss some other versions of Lagrangian multiform theory, applicable to integrable PDEs, differential-difference equations, and fully discrete lattice equations.

Contributed talks

Safe online learning-based control for an aerial robot with manipulator arms

Omayra Yago
(Universidad Complutense de Madrid, Spain)

We present a learning-based tracking controller based on Gaussian processes (GP) for the tracking control of an aerial vehicle equipped with manipulator arms. We present how to design the controllers for our system with partially unknown dynamics. We employ GP regression in order to compensate for the unknown dynamics of the system. In particular, the proposed control law provides asymptotic stability while tracking a desired trajectory and provides safety guarantees, that is, we can give a prediction of the uncertainty determined by the unknown dynamics.

Geometric methods for designing optimal filters on Lie groups

Damiano Rigo
(University of Verona, Italy)

In control theory, the problem of having available good measurements is of primary importance in order to perform good tracking and control. Unfortunately, in real-life applications, sensing systems do not provide direct measurements about the pose (and its rate) of mechanical systems, while, in other situations, measurements are so noisy that require pre-processing to filter out disturbances and biases. These problems could be faced by using filters and observers. We apply a second-order optimal minimum-energy filter constructed on Lie groups to several planar bodies. We studied the application of the filter to the matrix Lie group TSE(2); moreover, a comparison with the extended Kalman filter is presented. After that, we considered the Chaplygin sleigh case, which is a mechanical system with a nonholonomic constraint. Finally, we applied the filter to a real case scenario consisting of a scaled model representing a parking truck semi-trailer system. Particular attention is paid to the description of the geometric structure that underlies the dynamics and to the choice of the measurement equation, the affine connection, and the other parameters that define the filters. Simulations show the effectiveness of the proposed filters. The use of Lie groups theory for designing the filters is challenging, but the accuracy of the results, obtained considering the geometric structure and the symmetries of the system justifies the effort.

Reduction by Symmetry and Optimal Control in Riemannian Homogeneous Spaces

Jacob Goodman
(Antonio de Nebrija University, Spain)

In this talk, we derive the necessary conditions for optimality in a first-order variational problem on Riemannian homogeneous spaces by making use of the second fundamental form, reinterpreted as a connection on a horizontal distribution on the underlying Lie group. We assume that the action functional admits partial symmetry over some parameter manifold, and use this to reduce the necessary conditions by symmetry. These results are then applied to study a class of optimal control problems on homogeneous spaces, and the particular example of motion planning of robotic manipulators with obstacle avoidance is considered.

Virtual constraints on Lie groups

Efstratios Stratoglou
(Universidad Politécnica de Madrid, Spain)

Virtual constraints are relations imposed on a control system that become invariant via feedback control, as opposed to physical constraints acting on the system. Nonholonomic systems are mechanical systems with non-integrable constraints on the velocities. In this talk, we introduce the notion of virtual nonholonomic constraints on a Lie group in a geometric framework which is a controlled invariant subspace of the Lie algebra associated with the Lie group, and we show the existence and uniqueness of a control law preserving this subspace. We illustrate the theory with various examples and present simulation results for an application.

Floer theory in the analysis of Hamiltonian systems

Jagna Wiśniewska
(Universitat Politècnica de Catalunya, Spain)

Modern symplectic geometry started as a mathematical formulation of classical mechanics. Examples of Hamiltonian dynamical systems arise in celestial mechanics or electromagnetism. Rabinowitz Floer homology captures the relation between closed solutions of Hamilton's equations with a fixed energy and the geometry of the corresponding energy hypersurface. Even in the cases where the explicit solutions of Hamilton's equations cannot be computed, Rabinowitz Floer homology might still be computable and provide information about the existence of closed orbits.

Rolling Reductive Homogeneous Spaces

Markus Schlarb
(Julius-Maximilians-Universität Würzburg, Germany)

Rollings of a manifold M over another manifold $\widehat{M}$ of equal dimension without twist and without slip can be investigated from an intrinsic as well as an extrinsic point of view. In this talk, I focus on intrinsic rollings of reductive homogeneous spaces. More precisely, if G/H is a reductive homogeneous space equipped with some invariant covariant derivative, where the reductive decomposition $\mathfrak{g} = \mathfrak{h} \oplus \mathfrak{m}$ is fixed, rollings of $\mathfrak{m}$ over G/H are studied.

In this setting, an explicit description of the configuration space as well as the distribution characterizing intrinsic rollings of $\mathfrak{m}$ over G/H can be derived. Moreover, by studying a principal fiber bundle over the configuration space equipped with a suitable principal connection, the so-called kinematic equation is obtained. That is, for a given control curve, a time-variant ODE on a Lie group whose solutions, projected to the configuration space, are intrinsic rollings of $\mathfrak{m}$ over G/H.

Integrable and chaotic generalizations of the rolling of a convex body without slipping on a plane

Mariana Costa
(University of Padova, Italy)

The problem of a convex body rolling without slipping on a plane is a classic example in nonholonomic mechanics. In the literature there are several examples of affine variations of this system, in particular, solids rolling on a plane whose points move according to the flow of a given vector field. We will consider a further generalization of this problem in which we also allow the points on the surface of the body to move following the flow of another vector field. During the talk, I will present the equations of motion in the most general case and discuss special cases of existence of first integrals and a smooth invariant measure. This information will allow us to show that the dynamics ranges from integrable to chaotic according to the specifics of the system. I will also discuss how some of these systems can be physically realized and describe some remarkable phenomena exhibited in some very special cases.

On the stability of contact Hamiltonian systems

Asier López-Gordón
(ICMAT - CSIC, Spain)

In this talk, different techniques to study the stability properties of the zeros of contact Hamiltonian vector fields will be explained. Furthermore, a criteria to ensure that a dynamical system on an odd-dimensional manifold can be described as a contact Hamiltonian system will be provided. The so-called dissipated quantities (which, in several aspects, amount to conserved quantities in Hamiltonian systems) are utilised to investigate the stability of contact Hamiltonian systems.

Gong session

Coisotropic reduction in different phase spaces

Rubén Izquierdo
(Universidad Complutense de Madrid - ICMAT, Spain)

In a classical mechanical system, depending on the underlying phase space, there is a Poisson bracket (which is the case for symplectic and cosymplectic manifolds) or a Jacobi bracket (in the case of contact and cocontact manifolds). With these brackets we can define coisotropic submanifolds, which we can quotient by a canonical involutive distribution on the submanifold. The aim of this talk is to study the different types of inherited structures on these quotients, depending on the relative position of the submanifold to certain canonical distributions defined on the phase space.

A Review on Reduction and Reconstruction of Dynamics in Symplectic Geometry

Samuel Luque Astorga
(Universidad Complutense de Madrid, Spain)

The aim of this talk is to briefly summarize reduction and reconstruction of dynamics in symplectic geometry for Hamiltonian and hyperregular Lagrangian systems. We review classic results and outline possible generalizations.

Canonical lifts in Multisymplectic De Donder–Weyl Hamiltonian Field Theories

Arnoldo Guerra IV
(Universitat de Barcelona, Spain)

This talk will focus on the construction of canonical lifts of group actions and their generating vector fields to the first-jet and first-jet dual bundles on which the Lagrangian and De Donder–Weyl Hamiltonian formalisms for first-order field theories take place. Our work introduces the notion of a canonical lift in the De Donder–Weyl Hamiltonian formalism, for both regular and singular field theories, while the Lagrangian analog has been well known for many years. The importance of canonical lifts in defining natural symmetries will be emphasized in our Hamiltonian construction. Our work will be illustrated in an example field theory: Einstein–Cartan gravity in $3+1$ dimensions.

A Brownian–Markov Stochastic Model for Cart-like Wheeled Mobile Robots

Federico Vesentini
(University of Verona, Italy)

Wheeled mobile robots are commonly used in a wide range of applications from automated warehouses to patrolling. A rigorous and accurate model describing their dynamics is then important for control and tracking. It is worth mentioning that the majority of these models in literature deal with deterministic settings. Therefore, they are not able to take into account stochastic uncertainty or non-predictable phenomena such as lateral grip loss. In this paper, we present a novel stochastic dynamic model which considers random perturbations, while also considering the effect of unknown dissipative external forces acting on wheeled mobile robots. In particular, our approach is based on a two-state hybrid system of Stochastic Differential Equations modeling the robot dynamics subject to Brownian motion noises, with transitions from one state to the other triggered by to a homogeneous Markov chain.

Poisson cohomology of b^m-Poisson manifolds

Pablo Nicolás
(Universitat Politècnica de Catalunya, Spain)

Poisson geometry is a vast generalization of the Hamiltonian setting of classical mechanics, described abstractly by symplectic geometry. The deformation theory of a Poisson manifold (M, Π) is governed by the cohomology of the Lichnerowicz complex $(\mathfrak{X}^\bullet, \mathrm{d}_\Pi)$, called Poisson cohomology. The cohomology groups are generally infinite-dimensional, and explicit formulae are known for few Poisson manifolds.

In this talk, we compute the Poisson cohomology groups of b^m-Poisson manifolds, motivated by a question of Alan Weinstein. We follow the line of Guillemin, Miranda, and Pires used to compute Poisson cohomology for b-manifolds. A key lemma due to Mărcuţ and Osorno does not hold for b^m-Poisson cohomology. The failure of this result is measured by the cohomology of the quotient complex $\mathfrak{X}^\bullet / {}^{b^m}\mathfrak{X}^\bullet$. By appropriately localizing this complex and using semi-local normal forms for b^m-Poisson structures, we are able to compute its cohomology groups. The Poisson cohomology groups of the manifold are obtained by means of the induced long exact sequence in cohomology. Time permitting, we will analyze the cohomology of b^m-surfaces by deblogging the Poisson structure.

A representation theory approach to Lie–Hamilton systems based on $\mathfrak{sp}(4,\mathbb{R})$ and applications

Óscar Carballal
(Universidad Complutense de Madrid, Spain)

Lie–Hamilton systems are first-order systems of differential equations possessing a (non-linear) superposition rule which are compatible with a certain symplectic structure. They have been widely studied and classified under local diffeomorphisms on the real plane $\mathbb{R}^2$. Nevertheless, there are few examples of higher-dimensional Lie–Hamilton systems which do not come from lower-dimensional systems. For the more general case of Lie systems, it was shown recently that higher-dimensional Lie systems (even nonlinear ones) can be constructed through a representation theory approach.

In this talk we will propose a new method which allows us to obtain higher-dimensional Lie–Hamilton systems, mainly based on ideas coming from the representation theory of Lie algebras. We will focus on 4-dimensional Lie–Hamilton systems which we will interpret as systems on the configuration space $T^*\mathbb{R}^2 \simeq \mathbb{R}^4$, particularly obtaining t-dependent Hamiltonian systems with a Lorentzian kinetic energy coming from the Lorentz algebra $\mathfrak{so}(3,1)$. As we will show, the symplectic Lie algebra $\mathfrak{sp}(4,\mathbb{R})$ will play a prominent role when constructing these systems, which we will prove that are intrinsic, in the sense that they are not locally diffeomorphic to lower-dimensional systems.

Posters

Deformation of algebroid bracket of differential forms

Karolina Wojciechowicz
(University of Bialystok, Poland)

We construct the family of algebroid brackets on the tangent bundle T^*M to a Poisson manifold (M, π) starting from an algebroid bracket of differential forms. We use these brackets to generate Poisson structures on the tangent bundle TM. Next, in the case when M is equipped with a bi-Hamiltonian structure (M, π_1, π_2) we show how to construct another family of Poisson structures. Moreover we present how to find Casimir functions for those structures and we discuss some particular examples.

Integrable systems on the symplectic realizations of $\mathbf{e}(3)^*$

Elwira Wawreniuk
(University of Białystok, Poland)

Using the $U(2,2)$-invariant symplectic structure of the Penrose twistor space we find full and complete $E(3)$-equivariant symplectic realizations of some Poisson submanifolds of the Lie-Poisson space $\mathbf{e}(3)^* \equiv \mathbb{R}^3 \times \mathbb{R}^3$ dual to the Lie algebra $\mathbf{e}(3)$ of the Euclidean group $E(3)$, which is an underlying space in the rigid body theory. Considering concrete integrable cases of gyrostat systems on $\mathbf{e}(3)^*$ we can take their liftings to the ones on the constructed symplectic realizations. This way we obtain integrable systems on the phase spaces given by the symplectic realizations.

Complex analytic Lie systems, multisymplectic geometry and applications

Tymon Frelik
(University of Warsaw, Poland)

A Lie system is a t-dependent first-order system of differential equations in normal form whose general solution can be written as a t-independent function of several generic particular solutions and some constants to be related to initial conditions. The case of complex analytic Lie systems has been scarcely studied so far in the literature. We here present an ongoing study in such Lie systems associated with a compatible complex multisymplectic form. Our theoretical results are applied to study the complex Schwarzian derivative, which notably occurs in conformal field theory, integrable systems, etcetera.

The method of field characteristics

Dzianis Zhalukevich
(UWB, Belarus)

In this work, a method similar to the Maxwell electrodynamics method is used. The essence of this method is to determine the flows and circulations for fluid mechanics, the relationship of these quantities with each other is sought, which is the field characteristics. Based on the field characteristics, a qualitative theory of Newton's autonomous equations on the plane and in space is constructed.

On supersymplectic reductions

Adam Maskalaniec
(University of Warsaw, Poland)

After briefly introducing supergeometry, we review the theory of supersymplectic manifolds so as to investigate their Marsden–Weinstein reductions. Special types of supersymplectic forms, super-Hamiltonian vector fields, and other related notions are presented, some for the first time. Our supersymplectic counterpart requires the introduction of special changes that make the theory similar to a super analogue of two-symplectic geometry.

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k-contact Lie systems

Tomasz Sobczak
(University of Warsaw, Poland)

This poster introduces k-contact geometry and it relates it to the so-called k-symplectic geometry, extended to the k-contact cases some properties known in contact geometry. In general, k-contact geometry is mainly used to study field theories, but we here develop a new approach to study ordinary differential equations.

Then, we use our results to analyse a particular type of systems of first-order differential equations, the so-called *Lie systems*, whose properties are determined by a Lie algebra of vector fields of Hamiltonian vector fields relative to a k-contact structure. The obtained systems, the hereafter called k-contact Lie systems, are analysed and applied to study relevant systems of ordinary differential equations with applications in physics and mathematics.

Multicontact framework for non-conservative field theories

Xavier Rivas
(Universidad Internacional de La Rioja, Spain)

A new geometric structure inspired by multisymplectic and contact geometries, called *multicontact structure*, has been developed recently to describe non-conservative and action-dependent classical field theories. We review the main features of this formulation, showing how it is applied to study some classical theories in theoretical physics which are modified in order to include action-dependence; namely: the modified Klein-Gordon equation, and the action-dependent bosonic string.

An energy-momentum method for ODEs admitting a k-symplectic structure

Bartosz Maciej Zawora
(University of Warsaw, Poland)

A k-symplectic manifold is a pair $(P, \boldsymbol{\omega})$, where P is a manifold, while $\boldsymbol{\omega} \in \Omega^2(P, \mathbb{R}^k)$ is a closed $\mathbb{R}^k$-valued differential two-form such that $\ker \boldsymbol{\omega} = 0$. The k-symplectic Marsden–Weinstein reduction theorem allows for reducing a k-symplectic Hamiltonian system, denoted as $(P, \boldsymbol{\omega}, \boldsymbol{h})$, which admits a Lie group action $\Phi : G \times P \to P$ leaving a $\mathbb{R}^k$-valued function $\boldsymbol{h}$, where $\iota_X \boldsymbol{\omega} = d\boldsymbol{h}$ for some vector field X and $\boldsymbol{\omega}$ invariant. Particularly, via the Ad^k-equivariant k-symplectic momentum map $\mathbf{J}^\Phi : P \to (\mathfrak{g}^*)^k$ induced by Φ, where $\mathfrak{g}$ is the Lie algebra of G, one can find conditions to guarantee the existence of a reduced k-symplectic Hamiltonian system $(\mathbf{J}^{\Phi-1}(\boldsymbol{\mu})/G_{\boldsymbol{\mu}}, \boldsymbol{\omega}_{\boldsymbol{\mu}}, \boldsymbol{h}_{\boldsymbol{\mu}})$, where $G_{\boldsymbol{\mu}}$ is the isotropy subgroup of $\boldsymbol{\mu} \in (\mathfrak{g}^*)^k$ relative to the coadjoint action $\mathrm{Ad}^k : G \times (\mathfrak{g}^*)^k \to (\mathfrak{g}^*)^k$ and $\boldsymbol{h}_{\boldsymbol{\mu}}$ is a $\mathbb{R}^k$-valued function on $\mathbf{J}^{\Phi-1}(\boldsymbol{\mu})/G_{\boldsymbol{\mu}}$ whose pull-back to $\mathbf{J}^{\Phi-1}(\boldsymbol{\mu})$ retrieves the value of $\boldsymbol{h}$ on it.

Our poster presents an extension of the classical energy-momentum method to k-symplectic manifolds for studying, by means of $\boldsymbol{h}$, the stability close to the equilibrium points of a reduced k-symplectic Hamiltonian system $(\mathbf{J}^{\Phi-1}(\boldsymbol{\mu})/G_{\boldsymbol{\mu}},$

$\boldsymbol{\omega}_{\boldsymbol{\mu}}, \boldsymbol{h}_{\boldsymbol{\mu}})$, i.e. points in P where the projection of the vector field X vanishes, and the analysis of solutions of $(P, \boldsymbol{\omega}, \boldsymbol{h})$ near points in P that project onto equilibrium points of $(\mathbf{J}^{\Phi-1}(\boldsymbol{\mu})/G_{\boldsymbol{\mu}}, \boldsymbol{\omega}, \boldsymbol{h}_{\boldsymbol{\mu}})$ via the projection $\pi_{\boldsymbol{\mu}} : \mathbf{J}^{\Phi-1}(\boldsymbol{\mu}) \to \mathbf{J}^{\Phi-1}(\boldsymbol{\mu})/G_{\boldsymbol{\mu}}$. Additionally, we will explain that the Ad^{*k}-equivariance property of a k-symplectic momentum map $\mathbf{J}^{\Phi}$ may be omitted due to existence of the so-called affine action $\boldsymbol{\Delta} : G \times (\mathfrak{g}^*)^k \to (\mathfrak{g}^*)^k$, ensuring $\boldsymbol{\Delta}$-equivariance of $\mathbf{J}^{\Phi}$.

Participants

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