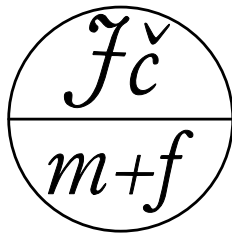# THE 38ᵗʰ WINTER SCHOOL
GEOMETRY AND PHYSICS

SRNÍ, CZECH REPUBLIC

JANUARY 13–20, 2018

Sponsored by

RSJ

LIST OF PARTICIPANTS

Ľudovít Balko

Klaus Bering

Martin Čadek

Andreas Čap

Boris Doubrov

Zdeněk Dušek

Fotis Farakos

Kara Farnsworth

Domenico Fiorenza

Matthias Fischmann

Roman Golovko

Rod Gover

Jan Gregorovič

Maxim Grigoriev

Karmen Grizelj

Aliaksandr Hancharuk

Ondřej Hulík

Denis Husadžić

Goce Chadzitaskos

Branislav Jurčo

Igor Khavkine

Shinyoung Kim

Pavel Kočí

Danica Kosanovic

Ilya Kossovskiy

Alexei Kotov

Konstantinos Koutrolikos

Peter Kristel

Lukáš Krump

Svatopluk Krýsl

Radoslaw Kycia

Thomas Lada

Emanuele Latini

Roman Lávička

Van Le

Renann Lipinski Jusinskas

Martin Markl

Rafael Mrđen

Jiří Nárožný

Jan Novák

Pavle Pandžič

Lada Peksová

Tomáš Procházka

Roland Púček

Jan Pulmann

Michael Reiter

Tomáš Rusin

Katja Sagerschnig

Tomáš Salač

Yuqing Shi

Martin Schnabl

Jan Slovák

Vladimír Souček

Radek Suchánek

Piotr Sułkowski

Josef Šilhan

Peter Teichner

Jiří Tolar

Vít Tuček

Jiří Vanžura

Rikard von Unge

Jakub Vosmera

Jan Vysoký

Andrew Waldron

Alice Waterhouse

Felix Wierstra

Travis Willse

Henrik Winther

Lenka Zalabová

Igor Zelenko

Petr Zima

Alexander Zuevsky

Vojtěch Žádník

ANNOUNCED LECTURES

A. INVITED LECTURES

Domenico Fiorenza: *T-duality in rational homotopy theory*

Rod Gover: *Compactification, boundary calculus, and applications*

Maxim Grigoriev: *Gauge invariant PDE, AKSZ sigma models, and higher spin fields*

Piotr Sułkowski: *Physics of knots – from Chern-Simons theory to quivers*

Peter Teichner: *An integer-valued Kontsevich integral – Goodwillie/Weiss approximations to the space of knots*

Andrew Waldron: *Singular Volume Problems and Contact Quantum Mechanics*

B. OTHER LECTURES

Klaus Bering: *TBA*

Andreas Čap: *Canonical Cartan connections associated to filtered G-structures*

Boris Doubrov: *Singular varieties and abnormal extremals of parabolic geometries*

Zdeněk Dušek: *Wrong steps in Finsler geometry related to homogeneous geodesics*

Fotis Farakos: *New D-term uplift*

Kara Farnsworth: *Weyl vs. Conformal Invariance in Quantum Field Theory*

Matthias Fischmann: *Recent developments on conformal symmetry breaking operators*

Roman Golovko: *The wrapped Fukaya category of a Weinstein manifold is generated by the cocores of the critical Weinstein handles*

Jan Gregorovič: *Models of 2-nondegenerate CR manifolds*

Ondřej Hulík: *TBA*

Goce Chadzitaskos: *Generalization of Shmushkevich method for collisions of particles*

Igor Khavkine: *Explicit triangular decoupling of vector and tensor mode equation on Schwarzschild*

Shinyoung Kim: *TBA*

Pavel Koči: *Matter coupling to higher spin supermultiplets*

Ilya Kossovskiy: *A normal form for 2-nondegenerate hypersurfaces*

Radoslaw Kycia: *Topological analysis of nuclear pasta phases*

Thomas Lada: *TBA*

Emanuele Latini: *Quantum Principal bundle*

Roman Lávička: *TBA*

Van Le: *Frölicher–Nijenhuis bracket and derived invariants of Riemannian manifolds provided with a parallel form of even degree*

Renann Lipinski Jusinskas: *Ambitwistor strings in the pure spinor formalism*

Jan Novák: *Coupled scalar perturbations of Galileon cosmologies in the mechanical approach in the late Universe*

Pavle Pandžič: *Dirac cohomology for modules over quantum $\mathfrak{sl}(2)$*

Jan Pulmann: *Kontsevich integral for a non-even associator and cabling.*

Michael Reiter: *Local rigidity of holomorphic maps of real manifolds*

Tomáš Rusin: *On the cup-length of the oriented Grassmann manifold and the characteristic rank of its canonical bundle*

Katja Sagerschnig: *Marked contact twisted cubic structures*

Tomáš Salač: *Monogenic hull and twistor theory*

Martin Schnabl: *TBA*

Jan Slovák: *TBA*

Vladimír Souček: *TBA*

Josef Šilhan: *TBA*

Jiří Tolar: *On Clifford groups in quantum computing*

Jakub Vosmera: *$\widehat{\mathfrak{u}}(1)$-breaking branes for $c = 2$ free bosons from minimal models*

Jan Vysoký: *Poisson-Lie T-duality revisited: Language of Courant algebroids*

Felix Wierstra: *Hopf invariants in real and rational homotopy theory*

Travis Willse: *Sasaki-Einstein metrics and their compactifications via projective geometry*

Lenka Zalabová: *Local geometric control of a certain mechanism with growth vector $(4, 7)$*

Igor Zelenko: *On geometry of 2-nondegenerate CR structures of hypersurface type via bigraded Tanaka prolongation.*

Petr Zima: *Killing equations on Riemannian spaces of constant curvature*

ABSTRACTS

Andreas Čap: *Canonical Cartan connections associated to filtered G–structures*

My lecture will be devoted to the filtered version of first order G–structures. This is a very general class of geometric structures, including parabolic geometries, several kinds of generic distributions, and geometries equivalent to systems of ODEs. After discussing the general concept of such structures, I will outline a recent general construction of canonical Cartan connections associated to them. This starting point of this construction is a candidate (in a very weak sense) for a homogeneous model and the only ingredient needed to apply the construction is an appropriate version of a normalization condition. In particular, only finite dimensional verifications are needed to decide whether the construction applies.

Boris Doubrov: *Singular varieties and abnormal extremals of parabolic geometries*

Singular varieties of non–holonomic vector distributions are used in the geometric control theory to define so–called abnormal extremals. We explore examples of such singular varieties and equations on abnormal extremals in case of vector distributions associated with parabolic geometries. In many examples we get certain correspondence spaces and are able to get a new interpretation of fundamental invariants of the initial parabolic geometry.

Zdeněk Dušek: *Wrong steps in Finsler geometry related to homogeneous geodesics*

A well known result by O. Kowalski and J. Szenthe says that any homogeneous Riemannian manifold admits a homogeneous geodesic through any point. Recently, attempts to prove an analogous result in Finsler geometry were done in [1] for odd dimension and in [2] in general. Unfortunately, both proofs in these papers are wrong. The main goal of the present talk is to demonstrate the wrong steps in these proofs with counterexamples.

The author proved the existence of a homogeneous geodesic in any odd–dimensional homogeneous Finsler space and in certain special homogeneous Finsler spaces of arbitrary dimension using another approach developed earlier for affine homogeneous manifolds. The general case is still open.

[1] Yan, Z.: Existence of homogeneous geodesics on homogeneous Finsler spaces of odd dimension, Monatsh. Math., 182,1, 165–171 (2017)

[2] Yan, Z., Huang, L.: On the existence of homogeneous geodesic in homogeneous Finsler spaces, J. Geom. Phys., 124, 264–267 (2018)

Fotis Farakos: *New D–term uplift*

We present a new type of D–term uplift in supergravity.

Kara Farnsworth: *Weyl vs. Conformal Invariance in Quantum Field Theory*

I will argue that conformal invariance in flat spacetime implies Weyl invariance in a general curved background metric for all unitary quantum field theories in spacetime dimensions $d \leq 10$. The arguments are based on algebraic consistency conditions similar to the Wess-Zumino consistency conditions that classify possible local anomalies.

Domenico Fiorenza: *T–duality in rational homotopy theory*

Sullivan models from rational homotopy theory can be used to describe a duality in string theory. Namely, what in string theory is known as topological T–duality between K^0–cocycles in type IIA string theory and K^1–cocycles in type IIB string theory, or as Hori's formula, can be recognized as a Fourier–Mukai transform between twisted cohomologies when looked through the lenses of rational homotopy theory. This is an example of topological T–duality in rational homotopy

theory, which can be completely formulated in terms of morphisms of L–infinity algebras. Based on joint work with Hisham Sati and Urs Schreiber (arXiv:1712.00758).

Matthias Fischmann: *Recent developments on conformal symmetry breaking operators*
We give new insight in the structure of conformal symmetry breaking operators and concentrate on the case when they become differential operators. The most important object to see this new structure is a second–order differential operator. This operator is not new at all, but its impact concerning conformal symmetry breaking differential operators was not seen before.

Roman Golovko: *The wrapped Fukaya category of a Weinstein manifold is generated by the cocores of the critical Weinstein handles*
We decompose any object in the wrapped Fukaya category of a $2n$–dimensional Weinstein manifold as a twisted complex built from the cocores of the n–dimensional handles in a Weinstein handle decomposition. This is joint work with Baptiste Chantraine, Georgios Dimitroglou Rizell and Paolo Ghiggini.

Jan Gregorovič: *Models of 2-nondegenerate CR manifolds*
I will show, how to assign to a regular point of a Levi degenerate CR manifold a second order symbol that carries more algebraic information about the CR manifold at that point. I will characterize all possible second order symbols of 2-nondegenerate CR manifolds and in particular, show how to construct a polynomial model for each possible second order symbol.

Goce Chadzitaskos: *Generalization of Shmushkevich method for collisions of particles*
Determination of relative probabilities of various channels of scattering and decay processes following from the invariance of the interactions with respect to a compact simple a Lie group, is the content of the talk. Aiming at the probabilities rather than Clebsch–Gordan coefficients, makes the task easier. This approach is inspired by the method of I. Shmushkevich, although his group of invariance was only SU(2), the isotopic spin. Simultaneous consideration of all the possible channels and corresponding resonances gives the probabilities for the product of particle collisions.

Igor Khavkine: *Explicit triangular decoupling of vector and tensor mode equation on Schwarzschild*
The vector and tensor (aka Lichnerowicz) wave equations have rich geometric properties and are naturally motivated by the study of classical and quantum, respectively, electromagnetic and gravitational perturbations on curved spacetimes. On the Schwarzschild black hole background, both of these equations admit a complete separation of variables. The resulting radial mode equations are complicated coupled systems of ODEs with rational coefficients. The geometric properties of these equations enable us to use an abstract strategy, based on the formal theory of differential equations, to partially decouple these systems into triangular form. This triangular form can then be greatly reduced. But we can prove, using the algebraic theory of ODEs with rational coefficients, that it cannot be completely reduced to diagonal form while maintaining rational coefficients. [arXiv:1711.00585].

Ilya Kossovskiy: *A normal form for 2-nondegenerate hypersurfaces*
In this joint work with Martin Kolar, we construct a complete normal form for 2-nondegenerate hypersurfaces in $\mathbb{C}^3$ (which also develops to higher dimensions). The normal form is unique up to the automorphism group of the model (= the tube over the future light cone). We apply the result to describing automorphisms of the respective real hypersurfaces in complex space.

Pavel Koči: *Matter coupling to higher spin supermultiplets*

In this talk I will discuss cubic interactions between matter supermultiplets and higher spin supermultiplets, using the superspace Noether procedure. We show that the resulting cubic vertices can be found only for the transverse half–integer version of higher spin multiplets. We also study the chiral–complex linear duality in the presence of higher spin supermultiplets.

Radoslaw Kycia: *Topological analysis of nuclear pasta phases*

Analysis of nuclear pasta phases that occur in neutron stars are examined in terms of topological invariants. The talk is based on [1].
Bibliography: [1] R. A. Kycia, S. Kubis, W. Wójcik, 'Topological analysis of nuclear pasta phases', Phys. Rev. C 96, 025803

Emanuele Latini: *Quantum Principal bundle*

I will introduce the notion of quantum principal bundle over projective base. In particular I will discuss 2 examples of deformed parabolic geometrical structure.

Van Le: *Frölicher–Nijenhuis bracket and derived invariants of Riemannian manifolds provided with a parallel form of even degree*

In my talk I propose several methods to construct new invariants of Riemannian manifolds provided with a parallel form of even degree, using Frölicher–Nijenhuis bracket and various derived bracket constructions. My talk is based on joint works with Kotaro Kawai and Lorenz Schwachhöfer.

Renann Lipinski Jusinskas: *Ambitwistor strings in the pure spinor formalism*

The success of ambitwistor strings in providing a strong origin to the CHY amplitudes is re–markable. In this talk I will introduce the model within the pure spinor formalism, therefore making its quantization explicitly super Poincaré covariant. Also I will explain its relation with the so–called sectorized strings and how it can be viewed both as zero and infinite tension limits of the usual superstring.

Jan Novák: *Coupled scalar perturbations of Galileon cosmologies in the mechanical approach in the late Universe*

We investigate the Universe at the late stage of its evolution and inside the cell of uniformity 150 – 370 MPc. We consider the Universe to be filled at these scales with dust like matter, a minimally coupled Galileon field and radiation as matter sources. We will use the mechanical approach and therefore the peculiar velocities of the inhomogeneities as well as fluctuations of other perfect fluids are nonrelativistic. Such fluids are said to be coupled, because they are concentrated around inhomogeneities. We investigate the conditions under which the Galileon field can become coupled. We know from previous work that at background level coupled scalar field behave as a two–component perfect fluid: a network of frustrated cosmic string and cosmological constant. We found a correction for the Galileon field, which behaves like a matter.

Pavle Pandžič: *Dirac cohomology for modules over quantum $\mathfrak{sl}(2)$*

We introduce a Dirac operator for the quantum algebra $U_q(\mathfrak{sl}(2, C))$ and study its cohomology on various modules over this algebra, including the cases when q is a root of unity. This is joint work with Petr Somberg.

Jan Pulmann: *Kontsevich integral for a non–even associator and cabling.*

The Kontsevich integral is an invariant of knots and, more generally, of tangles. It can be calculated in a combinatorial manner by assigning values to over/under crossings, caps and cups

and associator, using a Drinfeld associator. *Cabling* is the operation of doubling one connected component of a tangle. Le and Murakami showed that, with appropriate normalization of caps and cups, the Kontsevich integral of a cabled tangle can be easily calculated, if one uses an even Drinfeld associator.

The Kontsevich integral can be used in deformation quantization of moduli spaces of flat connections. Inspired by this application, we show that one can not generalize the compatibility with cabling for a general associator.

This is a joint work with Pavol Ševera.

Michael Reiter: *Local rigidity of holomorphic maps of real manifolds*

For given two real manifolds M and N consider $H(M, N)$ the set of all holomorphic maps between M and N. The group G of automorphisms of M and N induces an action on $H(M, N)$. A map H is called locally rigid if close to H in $H(M, N)$ there are only maps which belong to the G-orbit of H. In this talk we provide conditions for the local rigidity of a given map. This is joint work with Giuseppe della Sala and Bernhard Lamel.

Tomáš Rusin: *On the cup-length of the oriented Grassmann manifold and the characteristic rank of its canonical bundle*

The characteristic rank is a recently introduced homotopy invariant of smooth connected compact manifolds measuring the degree up to which the $\mathbb{Z}_2$–cohomology ring of the manifold is generated by the Stiefel-Whitney classes of its tangent bundle. Similarly, one may also consider the characteristic rank of an arbitrary vector bundle. Under certain conditions, by determining the characteristic rank of a suitable vector bundle over a given manifold, one may obtain an upper bound on its $\mathbb{Z}_2$–cup-length. In particular, for the oriented Grassmann manifold $\widetilde{G}_{n,k} = SO(n)/(SO(k) \times SO(n-k))$ computation of the characteristic rank of its canonical bundle $\widetilde{\gamma}_{n,k}$ yields interesting estimates and for some infinite families of manifolds the exact values of their $\mathbb{Z}_2$–cup-length.

Katja Sagerschnig: *Marked contact twisted cubic structures*

In this talk we consider the flat G_2–contact structure equipped with a (local) section of the correspondence space, which can also be viewed as a foliation by special curves. We shall discuss our motivation to look at these structures, some results and open problems.

Tomáš Salač: *Monogenic hull and twistor theory*

The n–Cauchy–Fueter operator is an overdetermined first order differential operator which is natural for the almost quaternionic structures. A null solution of this operator is called a monogenic function. On the standard affine subset $\mathbb{Q}^n$ of the homogeneous model, any monogenic function is real analytic and thus, if f is a monogenic function on an open subset U of $\mathbb{Q}^n$ and if we view $\mathbb{Q}^n$ as a totally real submanifold of $\mathbb{C}^{4n}$, then there is an open subset $U^c \subset \mathbb{C}^{4n}$ such that:

  (i) $U^c \cap \mathbb{Q}^n = U$,
  (ii) f extends to to a (unique) holomorphic function on U^c.

Using the twistor theory, I will show that there is an open subset $\mathcal{H}(U)$ of $\mathbb{C}^{4n}$, called the *monogenic hull* of U, such that $\mathcal{H}(U) \cap \mathbb{Q}^n = U$ and each monogenic function on U extends to a holomorphic function on $\mathcal{H}(U)$.

Jiří Tolar: *On Clifford groups in quantum computing*

The term Clifford group was introduced in 1998 by D. Gottesmann in his investigation of quantum error–correcting codes. The simplest Clifford group in multiqubit quantum computation is generated by a restricted set of unitary Clifford gates – the Hadamard, $\pi/4$–phase and controlled–X

gates. Because of this restriction the Clifford model of quantum computation can be efficiently simulated on a classical computer (the Gottesmann–Knill theorem). However, this fact does not diminish the importance of the Clifford model, since it may serve as a suitable starting point for a full-fledged quantum computation.

In the general case of a single or composite quantum system with finite–dimensional Hilbert space the finite Weyl–Heisenberg group of unitary operators defines the quantum kinematics and the states of the quantum register. Then the corresponding Clifford group is defined as the group of unitary operators leaving the Weyl–Heisenberg group invariant. Our comprehensive results on symmetries of the Pauli gradings of quantum operator algebras (derived for single as well as arbitrary composite finite quantum systems) are shown to directly correspond to Clifford groups defined as quotients with respect to $U(1)$.

Jakub Vosmera: $\widehat{\mathfrak{u}}(1)$–*breaking branes for $c = 2$ free bosons from minimal models*

We show that at certain points in the moduli spaces of bosonic compactifications, the free boson Virasoro algebra admits rational extensions which do not contain the bosonic currents. We use these results to investigate BCFTs of some $c = 2$ branes which break the $\widehat{\mathfrak{u}}(1)$ gluing conditions.

Jan Vysoký: *Poisson–Lie T-duality revisited: Language of Courant algebroids*

In 1995 Klimčík and Ševera proposed a new kind of duality for two–dimensional sigma models targeted in two mutually dual Poisson–Lie groups. Recently, Ševera has shown that the geometry behind this so called Poisson–Lie T-duality corresponds to a reduction of certain Courant algebroids. During this talk, we will in recall the (Lie and Courant) algebroid content of the PLT scenario. Consequently, one can consider the duality on the level of effective actions corresponding to the dual sigma models. We propose a solution to this question using Levi–Civita connections on Courant algebroids. All necessary geometrical tools will be recalled during the talk.

Felix Wierstra: *Hopf invariants in real and rational homotopy theory*

Let $f, g : X \to Y$ be two maps between manifolds. One of the most elementary questions in topology is whether the maps f and g are homotopic or not. In this talk we will give a generalization of the Hopf invariant which is a complete invariant of the real or rational homotopy class of the maps f and g, i.e. f and g are real homotopic if and only if this invariant agrees.

Travis Willse: *Sasaki–Einstein metrics and their compactifications via projective geometry*

A Sasaki–Einstein metric of general signature determines a holonomy reduction of the projective tractor connection determined by its Levi–Civita connection to the special unitary group. We study the reverse, that is, investigate the geometry determined on a projective manifold by such a holonomy reduction. In general this determines a partition of the underlying manifold into three smooth submanifolds, two open submanifolds equipped with Sasaki–Einstein metrics, and a separating hypersurface equipped with a conformal structure locally induced by a CR–structure via the classical Fefferman construction. To carry out this program, we study the consequences of the intermediate holonomy reductions to the orthogonal, symplectic, and complex linear groups, which are of independent interest.

Lenka Zalabová: *Local geometric control of a certain mechanism with growth vector* $(4, 7)$

We introduce a plane mechanism such that its kinematic space is a generalized path geometry in dimension 7 and we study its controllability. We construct nilpotent approximation and study its geometric properties and optimal control.

Igor Zelenko: *On geometry of 2–nondegenerate CR structures of hypersurface type via bigraded Tanaka prolongation.*

The talk is devoted to the local geometry of 2–nondegenerate CR manifolds M of hypersurface type. An absolute parallelism for such structures was recently constructed independently by Isaev–Zaitsev, Medori–Spiro, and Pocchiola in the minimal possible dimension ($\dim M = 5$), and for $\dim M = 7$ in certain cases by C. Porter. We develop a bigraded analog of Tanaka's prolongation procedure to construct a canonical absolute parallelism for these CR structures in arbitrary (odd) dimension with Levi kernel of arbitrary admissible dimension, classify all bigraded Tanaka symbols in the case of one–dimensional Levi kernel, and find the bigraded Tanaka prolongation for symbols satisfying additional natural regularity assumptions. Most of the talk is based on the joint work with C. Porter, some of the results are obtained also in collaboration with D. Sykes.

Petr Zima: *Killing equations on Riemannian spaces of constant curvature*

The different types of so called Killing equations arise naturally in differential geometry and have also important applications in physics. We review two related approaches to analyze these equations, namely the prolongation procedure and the cone construction. Then we apply these methods to the cases of Killing forms, spinors and spinor–valued forms, and describe complete sets of solutions on Riemannian spaces of constant curvature. In particular, for special values of the Killing number we find additional solutions for spinor–valued forms which had not been known before. They exhibit some interesting phenomena implied by reducibility of the space of spinor–valued forms.

GENERAL INFORMATION

38th WINTER SCHOOL GEOMETRY AND PHYSICS
Srní, Czech Republic
January 13–20, 2018

`http://conference.math.muni.cz/srni/`

CONTACT

Geometry and Physics 2018
Department of Mathematics
Faculty of Sciences – Masaryk University
Kotlářská 2
611 37 Brno
Czech Republic

`srni@math.muni.cz`

ORGANIZED BY

Union of Czech Mathematicians and Physicists
Faculty of Mathematics and Physics, Charles University, Prague
Faculty of Science, Masaryk University, Brno

SPONSORED BY

HOTEL INFORMATION

Hotely Srní
Srní 117
341 94 Srní
Tel.: +420 376 599 212