XXXVI WORKSHOP ON GEOMETRIC METHODS IN PHYSICS

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XXXVI Workshop on Geometric Methods in Physics organized by Institute of Mathematics, University of Białystok, Ciołkowskiego 1M, 15-245 Białystok, Poland, e-mail: wgmp@uwb.edu.pl

This year, the XXXVI Workshop on Geometric Methods in Physics, includes a Special Memorial Session remembering and honoring our colleague and friend, Professor Syed Twareque Ali. Twareque (as we all knew him) was born in Bangladesh (then India) in 1942, and died unexpectedly in January 2016. He received his doctorate from the University of Rochester, working with Gérard Emch, and after holding several different research positions, joined the mathematics faculty of Concordia University in Montréal in 1981 where he became a full professor in 1990. As a mathematical physicist, he achieved wide recognition for his studies of quantization methods, coherent states and symmetries, and wavelet analysis. He was a generous supporter of the WGMP meetings, attending virtually every meeting from 1991 to 2015. He was also a long-time member of our organizing committee, and co-edited most of the Proceedings volumes. In memory, he continues to inspire us to find achieve deeper mathematical and scientific understandings here in the beautiful Białowieża Forest setting that he loved.

LIST OF ABSTRACTS

Plenary lectures

1. **Fedor BOGOMOLOV** – *New York University, USA*

   Symmetric tensors and the geometry of subvarieties of $\mathbb{P}^N$

   In my talk I discuss the relation between special properties of tangent variety of a smooth complex projective subvariety in a projective space and symmetric differential with coefficients on the variety.

2. **Ludwik DĄBROWSKI** – *SISSA, Italy*

   Fundamental fermions as inner noncommutative forms

   I will recall the spectral triple describing the noncommutative geometry of the standard model of fundamental particles. The associated spectral triple is the product of the canonical one corresponding to the Dirac spinors on an external spin-manifold, with an finite one, which is a suitable analogue of differential forms on a finite quantum internal space.

3. **Yakov ELIASHBERG** – *Stanford University, USA*

   Classical and quantum integrable systems arising from Symplectic Field Theory

4. **Toshiyuki KOBAYASHI** – *The University of Tokyo, Japan*

   Conformally covariant symmetry breaking operators on differential forms and some applications

   We discuss restrictions of irreducible representations to reductive subgroups with focus on geometric question:

   Classification of conformally covariant symmetry breaking operators on differential forms.

   If time permits, we shall also discuss the following related questions for orthogonal groups of rank one.

   a) General background for restriction of infinite-dimensional representations of reductive groups
   b) Period of irreducible unitary representations.

   Refereces:

   1. T. Kobayashi. A program for branching problems in the representation theory of real reductive groups. Progr. Math. vol. 312, pp. 277-322, 2015.
   2. T. Kobayashi, T. Kubo, and M. Pevzner, Conformal symmetry breaking operators for differential forms on spheres, viii+192 pages. Lecture Notes in Mathematics, vol. 2170, 2016.
   3. T. Kobayashi and B. Speh. Symmetry Breaking for Representations of Rank One Orthogonal Groups, Memoirs of Amer. Math. Soc. 238. 2015. 118 pages.

5. **Yvette KOSMANN-SCHWARZBACH** – *Ecole Polytechnique (retired), France*

Beyond recursion operators

After brief historical remarks on the Nijenhuis torsion of $(1,1)$-tensors on manifolds and on the lesser-known Haantjes torsion, we shall show how the Haantjes manifolds of Magri and the Poisson–Haantjes structures of Tempesta and Tondo generalize the classical approach to integrable systems in the bi-hamiltonian and Poisson–Nijenhuis formalisms, replacing the sequence of powers of the recursion operator by a family of commuting Haantjes operators. We shall survey some applications of these new geometric methods.

6. **Gabriel LAROTONDA** – *CONICET / Universida de Buenos Aires, Argentina*

The geometric significance of Toeplitz kernels in the restricted Grassmannian

Let L^2 be the Lebesgue space of square-integrable functions on the unit circle. We show that the injectivity problem for Toeplitz operators is linked to the existence of minimizing geodesics in the Grassmann manifold of L^2. We also investigate this connection in the context of restricted Grassmann manifolds associated to p-Schatten ideals and essentially commuting projections. This is joint work in collaboration with Esteban Andruchow and Eduardo Chiumiento.

7. **Eugene LYTVYNOV** – *Swansea University, United Kingdom*

Gauge-invariant quasi-free states on the algebra of the anyon commutation relations

Let $X = \mathbb{R}^2$ and let $q \in \mathbb{C}$, $|q| = 1$. For $x = (x^1, x^2)$ and $y = (y^1, y^2)$ from X^2, we define a function $Q(x,y)$ to be equal to q if $x^1 < y^1$, to $\bar{q}$ if $x^1 > y^1$, and to $\Re q$ if $x^1 = y^1$. Let ∂_x^+, ∂_x^- $(x \in X)$ be operator-valued distributions such that ∂_x^+ is the adjoint of ∂_x^-. We say that ∂_x^+, ∂_x^- satisfy the anyon commutation relations (ACR) if $\partial_x^+ \partial_y^+ = Q(y,x)\partial_y^+ \partial_x^+$ for $x \neq y$ and $\partial_x^- \partial_y^+ = \delta(x-y) + Q(x,y)\partial_y^+ \partial_x^-$ for $(x,y) \in X^2$. In particular, for $q = 1$, the ACR become the canonical commutation relations and for $q = -1$, the ACR become the canonical anticommutation relations. We define the ACR algebra as the algebra generated by operator-valued integrals of ∂_x^+, ∂_x^-. We construct a class of gauge-invariant quasi-free states on the ACR algebra. Each state from this class is completely determined by a positive self-adjoint operator T on the real space $L^2(X, dx)$ which commutes with any operator of multiplication by a bounded function $\psi(x^1)$. In the case $\Re q < 0$, the operator T additionally satisfies $0 \leq T \leq -1/\Re q$. Further, for $T = \kappa^2 \mathbf{1}$ $(\kappa > 0)$, we discuss the corresponding particle density $\rho(x) := \partial_x^+ \partial_x^-$. For $\Re q \in (0,1]$, using a renormalization, we rigorously define a vacuum state on the commutative algebra generated by operator-valued integrals of $\rho(x)$. This state is given by a negative binomial point process. A scaling limit of these states as $\kappa \to \infty$ gives the gamma random measure, depending on parameter $\Re q$.

8. **Andrey MIRONOV** – *Sobolev Institute of Mathematics, Russia*

Integrable magnetic geodesic flows on 2-torus: new example via quasi-linear system of PDEs

The only one example has been known of magnetic geodesic flow on the 2-torus which has a polynomial in momenta integral independent of the Hamiltonian. In this example the integral is linear in momenta and corresponds to a one parametric group preserving the Lagrangian function of the magnetic flow. We consider the problem of integrability on one energy level. This problem can be reduced to a remarkable semi-hamiltonian system of quasi-linear PDEs and to the question of existence of smooth periodic solutions for this system. Our main result states that the pair of Liouville metric with zero magnetic field on the 2-torus can be analytically deformed to a Riemannian metric with small magnetic field so that the magnetic geodesic flow on an energy level is integrable by means of a quadratic in momenta integral. Thus our construction gives a new example of smooth periodic solution to the Semi-hamiltonian quasilinear system of PDEs. The talk is based on the joint paper with Misha Bialy (Tel-Aviv) and Sergey Agapov (Novosibirsk).

9. **Gerard MISIOLEK** – *University of Notre Dame, USA*

Information Geometry on diffeomorphism groups

I will describe an infinite-dimensional analogue of the Fisher-Rao metric on the quotient space of the group of diffeomorphisms of a compact Riemannian manifold by the subgroup of volume-preserving diffeomorphisms. Time permitting I will also describe Amari-Chentsov connections and the associated nonlinear PDE.

10. **Nicolai RESHETIKHIN** – *University of California, Berkeley, United States*

Limit shapes in solvable models in statistical mechanics

11. **Nikolai TYURIN** – *Bogoliubov Laboratory of Theoretical Physics / High School of Economics, Russia*

Special Bohr–Sommerfeld geometry: from Geometric Quantization to Mirror Symmetry

Bohr–Sommerfeld condition on lagrangian submanifolds and cycles in compact symplectic manifolds with integer symplectic forms has been used in several approaches to Geometric Quantization problem. We propose a new speciality condition on Bohr–Sommerfeld lagrangian cycles and show how these special Bohr–Sommerfeld lagrangian cycles can be exploited in the problem. On the other hand this new condition is extremely interesting been applied to algebraic varieties. F.e. for certain ample divisors in algebraic varieties one can construct almost canonically "lagrangian shadows" of these divisors.

12. **Alexander ZHEGLOV** – *Moscow State University, Russia*

Quantum integrable systems and torsion free sheaves on algebraic varieties

I will talk about the correspondence between quantum integrable systems and algebro-geometric spectral data. The most important ingredient of these data are spectral sheaves – torsion free sheaves of special kind on algebraic varieties. I will also discuss how explicit is this correspondence, in particular, could we produce integrable systems starting from spectral data, even if the spectral variety has dimension greater than one. Part of the results in the talk are joint work with Igor Burban (Cologne) and with Herbert Kurke (Berlin).

Contributed lectures

13. **Jeremy ATTARD** – *Centre de Physique Théorique, France*

The dressing field method of gauge symmetry reduction: presentation and examples

This talk is a presentation of a recent method of gauge symmetry reduction, distinct from well-known gauge fixing, bundle reduction theorem or even spontaneous symmetry breaking mechanism (SSBM). Given a symmetry group H acting on a fiber bundle and its naturally associated fields (Ehresmann (or Cartan) connection, curvature, ...) there sometimes exists a way to erase (in whole or in part) the H-action by just reconfiguring these fields, i.e. by making a mere change of field variables in order to get new («composite») fields on which H (in whole or in part) does not act anymore. Two examples: the re-interpretation of the BEHGHK (Higgs) mechanism without calling on a SSBM, and the top-down construction of Tractor and Twistor spaces and connections in the framework of conformal Cartan geometry, will be outlined at the end of the talk.

Refereces:

[1] arXiv:1001.1176 (about Higgs mechanism);

[2] arXiv:1212.6702 (the method + examples);

[3] arXiv:1512.06907 (dressing method and Weyl gravity);

[4] arXiv:1611.03891 and arXiv:1609.07307 (Tractors and Twistors).

14. **Mirela BABALIC** – *Institute for Basic Science, South Korea*

A differential model for B-type Landau–Ginzburg theories

We describe a mathematically rigorous differential model for B-type open-closed topological Landau–Ginzburg theories defined by a pair (X, W), where X is a non-compact Kahlerian manifold with holomorphically trivial canonical line bundle and W is a complex-valued holomorphic function defined on X and whose critical locus is compact but need not consist of isolated points. In this generality, we give rigorous constructions of the topological D-brane category, bulk algebra, bulk-boundary and boundary-bulk maps as well as of the bulk and boundary topological traces. We also show how this construction specializes to the case when X is Stein and W has finite critical set, in which case one recovers a simpler mathematical model.

15. **Fabio BAGARELLO** – *Università di Palermo, Italy*

Bi-coherent states

After a general analysis of the functional structure associated to pseudo-bosonic operators, I will discuss how to construct a pair of states sharing with Coherent States some of their properties. In particular, I will show that they are eigenstates of two different annihilation operators obeying pseudo-bosonic commutation rules, and that they, together, produce a resolution of the identity.

16. **Bogdan BALCERZAK** – *Łódź University of Technology, Poland*

On Dirac type operators determined by skew-symmetric 2-tensors on anchored vector bundles

Dirac type operators on anchored vector bundles (in particular on Lie algebroids) with respect to skew-symmetric 2-tensors will be defined and discussed. Classical

Dirac operators are determined by the Clifford algebra structures and connections, whilst considered Dirac type operators are determined by the Weyl algebras (the skew-symmetric counterpart of Clifford algebras) and connections. The Clifford algebra structures come from symmetric 2-tensors (eg. pseudo-Riemannian tensors), whereas the Weyl algebra structures are given by skew-symmetric 2-tensors (eg. by symplectic forms) or bivectors (eg. Poisson structures) on the given vector bundle or on its dual.

17. **Alexander BELAVIN** — *Landau Institute for Theoretical Physics, Russia*

A new approach to computation the Special geometry of Moduli spaces for a Calabi–Yau manifold

It is known that moduli spaces of Calabi–Yau manifolds are special Kahler manifolds. This structure determines corresponding low-energy effective theory which arises in Superstring compactifications on Calabi–Yau. In the case, where CY is given as a hypersurface in the weighted projective space, we propose a new procedure to compute the Kahler potential of the moduli space. Our method is based on the fact that the moduli space of Calabi–Yau manifolds is a marginal subspace of the Frobenius manifold.

18. **Daniel BELTIŢĂ** — *Institute of Mathematics "Simion Stoilow" of the Romanian Academy, Romania*

Quasidiagonality of C*-algebras of generalized $ax + b$ groups

We will discuss quasidiagonality properties of C^*-algebras of some solvable Lie groups. In particular, we present examples of amenable Lie groups whose C^*-algebras are non-quasidiagonal, in marked contrast to phenomena that occur for the amenable discrete groups.

19. **Roberto BENEDUCI** — *Università della Calabria, Italy*

Universal Markov Kernels for Quantum Observables

Positive operator valued measures play a crucial role in the modern formulation of quantum mechanics where they represent quantum observables as well as in quantum information theory since they are important for a range of quantum information processing protocols where classical post-processing plays a role. The spectral measures (also known as Projection Valued Measures or PVMs) are particular examples of POVMs and are able to describe only a very limited class of observables. Furthermore they are not able to give a clear mathematical representation of the joint measurability of two observables. For example, the noncommutativity of the position and momentum operators Q and P forbids a mathematical description of the joint measurement of position and momentum. Things go differently if position and momentum are represented by POVMs. Indeed, there are two commutative POVMs F^Q and F^P that are informationally equivalent to Q and P respectively and are the marginals of a joint POVM. Moreover F^Q and F^P are noisy versions of Q and P respectively. This is at the root of the formulation of quantum mechanics on phase space [1-3] where POVMs allow a rigorous quantization procedure. All that underlines the relevance of POVMs in general and of commutative POVMs in particular.

There are three characterizations of commutative POVMs [4-14] and one of them shows that every commutative POVM is the randomization of a spectral measure by means of a Markov kernel (or transition probability). That is exactly what happens in the phase space formulation of quantum mechanics when the symmetry group is the Heisenberg group, i.e., position and momen- tum are jointly described by a non commutative POVM whose marginals are randomization (through Markov kernels) of the position and momentum operators.

In the present work we analyze more in details the randomization procedure. In particular, we show that there is a universal Markov kernel μ. It is called universal because every commutative POVM F is the randomization of a particular spectral measure E^F by means of μ. Formally, we prove that there is a Markov kernel μ such that, for any real commutative POVM F

$$F(\Delta) = \int \mu_\Delta(\lambda) dE^F_\lambda$$

where E^F is a spectral measure which depends on F.

The talk will include a brief introduction to the relevance of POVMs in phase space quantum mechanics.

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20. **Stefan A.A. BERCEANU** – *"Horia Hulubei" National Institute of Physics and Nuclear Engineering, Romania*

Coherent states associated to the Jacobi group and Berezin quantization of the Siegel–Jacobi ball

Coherent states are associated to the Jacobi group. The metric obtained from the scalar product of coherent states based on the Siegel-Jacobi ball is a balanced metric. Several geometric properties of the Siegel–Jacobi ball are obtained via the methods of coherent states. We insist on geometric properties of the Siegel–Jacobi ball specific to Berezin quantization.

21. **Marco BERTOLA** – *Concordia University / SISSA, Canada*

Symplectic geometry of the moduli space of projective structures

The moduli space of quadratic differentials with simple zeroes can be endowed with a natural symplectic structure, due to Korotkin, which we call "homological symplectic structure".

On the other hand the affine bundle of projective connections (also to be defined) is modelled on the bundle of quadratic differentials.

By choosing a holomorphically varying base projective connection, the projective connections and the space of quadratic differentials can be naturally (but not canonically) identified.

Moreover, a projective connection defines a monodromy map and hence a point in the character variety, i.e. homomorphism of the fundamental group of a Riemann surface into unimodular two by two matrices modulo conjugations.

Goldman ('86) introduced a Poisson bracket on the character variety which, in this case, is symplectic.

Then the result is that the push forward of the homological symplectic structure to the character variety (by an appropriate choice of base projective connection) coincides with the Goldman bracket.

I hope to define all the necessary objects and be as elementary as possible.

This is joint work with Chaya Norton (Concordia) and Dmitry Korotkin (Concordia/CRM).

22. **Tomasz BRZEZIŃSKI** – *Swansea University / University of Białystok, United Kingdom / Poland*

Topology and K-theory of noncommutative weighted projective spaces

In this talk we present results obtained jointly with Simon Fairfax and Wojciech Szymański. Extending earlier results of Hong and Szymański we interpret all quantum lens spaces as graph C^*-algebras and thus design an efficient method for calculating K-groups of quantum lens spaces. Some special cases (not studied earlier) serve as an illustration. Using the freeness of the actions of the circle group on quantum lens spaces that define quantum weighted projective spaces we compute the K-groups of the latter.

23. **Goce CHADZITASKOS** – *Czech Technical University in Prague, Czech Republic*

The harmonic oscillator in a sector of plane and the angular momentum theory

We present the solution of a harmonic oscillator in a sector of a plane following an old observation of Marcos Moshisky (1984). According to this proposition, we show the connection with the graded angular momentum theory. We show, how to select the permissible angular momentum values for a given total energy of the harmonic oscillator in a sector of plane. All permissible values correspond to one subspace of the decomposition of space because of the boundary conditions.

24. **Edmund Y.-M. CHIANG** — *Hong Kong University of Science and Technology, Hong Kong*

Complex oscillation theory and semi-finite gap problem of Whittaker–Hill equation

(semi-)finite-gap potentials of Hill's equations have been important in both physics (e.g. solid state physics) and mathematics. We found explicit solutions of the semifinite gap solutions found earlier by Djakov and Mityagin and relate the solutions to Bank–Laine's complex oscillation (value distribution) theory of an Hill's equation.

25. **Jan DEREZIŃSKI** — *University of Warsaw, Poland*

Almost homogeneous Schroedinger operators

First I will describe a certain natural holomorphic family of closed operators with interesting spectral properties. These operators can be fully analyzed using just trigonometric functions.

Then I will discuss 1-dimensional Schroedinger operators with a $1/x^2$ potential with general boundary conditions, which I studied recently with S. Richard. Even though their description involves Bessel and Gamma functions, they turn out to be equivalent to the previous family.

Some operators that I will describe are homogeneous — they get multiplied by a constant after a change of the scale. In general, their homogeneity is weakly broken–scaling induces a simple but nontrivial flow in the parameter space. One can say (with some exaggeration) that they can be viewed as "toy models of the renormalization group".

26. **Marián FECKO** — *Comenius University, Slovakia*

Surfaces which behave like vortex lines

Within the general theory of integral invariants á la Poincaré and Cartan, one can find surfaces which "move with the fluid". The situation reduces to vortex lines and Helmholtz theorem when the general setting reduces to hydrodynamics of ideal fluid.

27. **Jean-Pierre GAZEAU** — *University Paris-Diderot, France*

2D Covariant Affine Integral Quantization(s)

Covariant affine integral quantization of the phase space (plane) X (punctured plane) is studied and applied to the motion of a particle in a punctured plane. We examine the consequences of different quantizer operators built from weight functions on the phase space. To illustrate the procedure, we examine two particulars example of weights. The first one corresponds to choice of coherent state, while the second corresponds to the affine inversion in the punctured plane. The later yields the usual canonical quantization and a quasi-probability distribution (2D affine Wigner function) which is real, marginal in both position and momentum vectors. An interesting application to the quantum rotating frame will be presented.

28. **Gerald GOLDIN** – *Rutgers University, USA*

Diffeomorphism group representations in relativistic quantum field theory

Unitary representations of diffeomorphism groups and their semidirect products are known to play a fundamental role in nonrelativistic (Galilean) quantum theory, describing the kinematics of a wide variety of physical systems. The infinitesimal generators of appropriate 1-parameter subgroups are the self-adjoint mass density and momentum flux density, which form a local current algebra. Furthermore, the irreducible, unitary diffeomorphism group representations fall naturally into hierarchies, whose intertwining operators create and annihilate configurations of the same kind. These intertwining operators have an interpretation as "second-quantized" fields. This talk focuses on the role played by the diffeomorphism group and its representations in relativistic quantum field theories. Here the mass and momentum densities are reference frame-dependent constructs, not local in spacetime and not Lorentz covariant. Nevertheless, they describe actual quantum measurements. Thus, we propose to start in a fixed reference frame, and with respect to that frame, to introduce the quantum kinematics described by the diffeomorphism group of "space" at fixed time. Only after constructing intertwining fields do we introduce the spacetime symmetry group (the PoincarÃ× group in this case), which provides the information needed to connect descriptions in the different frames of reference. Then we construct local relativistic fields out of the (noncovariant) intertwining fields. We work out this idea for the case of free relativistic scalar bosons, where we formally express the Hamiltonian explicitly in terms of the original density and current operators. The talk is based on joint work with D.H. Sharp (Los Alamos).

29. **Mahouton Norbert HOUNKONNOU** – *University of Abomey-Calavi, Republic of Benin*

Recursion operator in a noncommutative Minkowski phase space

30. **Jiří HRIVNÁK** – *Czech Technical University in Prague, Czech Republic*

Discrete Cosine and Sine transforms on Honeycomb lattice

The discrete Fourier-like analysis of generalized cosine and sine functions on the two-dimensional honeycomb lattice is presented. The theoretical background stems from the concept of Weyl-orbit functions, discretized simultaneously on the weight and root lattices of the Weyl group A_2. The introduced class of extended Weyl-orbit functions generalizes periodicity and boundary properties of the one-dimensional cosine and sine functions. Three types of discrete complex Fourier–Weyl transforms and three types of real-valued Hartley–Weyl transforms are detailed. Examples of unitary transform matrices and interpolation behavior of the discrete transform is demonstrated. Consequences of the developed discrete transforms for transversal eigenvibrations of the mechanical graphene model are discussed. This is a joint work with Lenka Motlochová.

31. **Fardin KHEIRANDISH** – *University of Kurdistan, Iran*

Electromagnetic field quantization in the presence of external fields and its applications

32. **Jerzy KIJOWSKI** — *Centrum Fizyki Teoretycznej, PAN, Poland*

Higher order curvature tensors, higher order Bianchi identities

33. **Bartosz KWAŚNIEWSKI** — *Uniwersytet w Białymstoku, Poland*

Aperiodicity, topological freeness and pure outerness: from group actions to Fell bundles

Several deep results on the relationship between various non-triviality conditions for group actions and the simplicity of reduced crossed products were proved around 1980 by Olesen-Pedersen, Kishimoto and Rieffel. They are applied by a number of authors in the study of the ideal structure and pure infiniteness of crossed products by actions of discrete groups.

We collect a number of this kind of results and generalize them to Fell bundles over discrete groups. We discuss conditions under which aperiodicity, topological freeness and pure outerness are equivalent, and also when they are necessary for the unit fibre of a Fell bundle to detect ideals in the reduced cross sectional C^*-algebra. (Based on joint work with Ralf Meyer.)

34. **Calin LAZAROIU** — *Institute for Basic Science, South Korea*

Real Lipschitz structures

I discuss the classification of real Lipschitz structures, a generalization of spin structures which provides the weakest condition under which a vector bundle on a pseudo-Riemannian manifold admits an inner Clifford multiplication. I also sketch a few applications of such structures to supergravity and string theories.

35. **Guowu MENG** — *Hong Kong University of Science and Technology, Hong Kong*

Jordan Algebra and Kepler Problem

It will be reported that there are many integrable models associated with each simple Euclidean Jordan algebra. These models all share the characteristic features of the Kepler problem such as the Laplace–Runge–Lenz vector.

36. **Bogdan MIELNIK** — *CINVESTAV, Mexico*

The Unreasonable Efficiency of Mathematics (E.Wigner): real or imaginary danger?

We argue that the trouble is not innocent enough to be neglected; we approach it by considering several quasi-quantum theories.

(a) The quantization in non-inertial frames,

(b) Unruh radiation,

(c) Entropy: one or many?

(d) Entropy of the black holes.

Some conceptual troubles are visible in all of them.

37. **Ali MOSTAFAZADEH** – *Koç University, Turkey*

Transfer Matrix Formulation of Scattering Theory, Invisibility, and Reciprocity in Two and Three Dimensions

We outline an alternative to the S-matrix formulation of scattering theory in two and three dimensions that relies on a multidimensional notion of transfer matrix. This enables us to obtain an exact solution of the scattering problem for delta function potentials in two and three dimensions. It also allows for establishing a genuinely multidimensional generalization of the Lorentz reciprocity principle and unidirectional invisibility. The former follows as a corollary of a theorem revealing a symplectic nature of the transfer matrix operator. It implies that in dimensions other than one the reciprocity principle does not prohibit nonreciprocal transmission. This is of particular significance for constructing linear optical and acoustic diodes, which was previously considered impossible. We offer concrete physical applications of our mathematical findings. In particular, we construct a physical model for an active optical wire with a rectangular cross-section that is invisible from one direction but scatters light coming from the opposite direction.

References: F. Loran and A. Mostafazadeh, Phys. Rev. A 93, 042707 (2016) and Proc. R. Soc. A 472, 20160250 (2016).

38. **Yurii NERETIN** – *Institute for Theoretical and Experimental Physics, Russia*

Reproducing kernels on the space of univalent functions

The space K of functions univalent in the unit disk and smooth up to the boundary is homogeneius space of the group of diffeomorphisms of the circle (a stabilizer of a point is the group pf rotations of the circle). The space K is an infinite-dimensional analog of Hermitian symmetric spaces. We write a two-parametric family of invariant reproducing kernels on K.

39. **Anatol ODZIJEWICZ** – *Uniwersytet w Białymstoku, Poland*

Coherent state map quantization

In this presentation we will describe a method of quantization of automorphisms of a G-principal bundle $P(G, \pi, M)$ with the given connection form α. This method is based on the construction of the morphism of the gauge groupoid $(P \times P)/G \rightrightarrows M$ into the Banach-Lie groupoid [1,2] $\mathcal{G}(\mathcal{M}) \rightrightarrows \mathcal{L}(\mathcal{M})$ of partially invertible elements of a W^*-algebra (von Neumann algebra) which has the lattice $\mathcal{L}(\mathcal{M})$ of the orthogonal projections of $\mathcal{M}$ as its base manifold. We will show that Kostant–Souriau–Kirillov geometric quantization as well as coherent state map quantization (reproducing kernel quantization) [3,4] are included in this theory as particular cases.

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40. **Aleksandr ORLOV** — *Institute of Oceanology / Higher School of Economics, Russia*

Quantum chaos and Hurwitz numbers

41. **Victor PALAMODOV** — *Tel Aviv University, Israel*

Non regular symplectic reduction and quantization of singular spaces

The algebraic method of singular reduction is applied for non regular group action providing a singular Poisson space. For some examples of singular Poisson spaces the deformation quantization is explicitly constructed. For the flat phase space with the classical moment map and the orthogonal group action the deformation quantization converges for the class of entire functions.

42. **Fernand PELLETIER** — *Université de Savoie Mont Blanc, France*

Conic sub-Hilbert-Finsler structure on a Banach manifold

A Hilbert–Finsler metric $\mathcal{F}$ on a Banach bundle $\pi : E \to M$ is a classical Finsler metric on E whose fundamental tensor is definite-positive. A conic Hilbert–Finsler metric F on E is a Hilbert–Finsler metric which is defined on an open conic submanifold of E. In the particular case where we have a (strong) Riemannian metric g on E then $\sqrt{g}$ is a natural example Hilbert–Finsler metric on E. According to [1], if moreover we have an anchor $\rho : E \to TM$ we get a sub-Riemannian structure on M that is g induces a "singular" Riemannian metric on the distribution $\mathcal{D} = \rho(E)$ on M . By analogy, a sub-Hilbert–Finsler structure on M is the data of conic Hilbert–Finsler metric F on a Banach bundle $\pi : E \to M$ and an anchor $\rho : E \to TM$. Of course we get a "singular" conic Hilbert–Finsler metric on $\mathcal{D} = \rho(E)$. In the finite dimensional sub-Riemanniann framework, it is well known that "normal extremals" are projection of Hamitonian trajectories and any such an extremal is locally minimizing (relative to the associated distance). Analogous results in the context of sub-Riemannian Banach manifold were obtained in [1]. By an adaption of the same arguments we generalize these properties to the sub-Hilbert–Finsler framework.

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43. **Michael PEVZNER** — *University of Reims, France*

Conformal symmetry breaking operators on AdS spaces

Let X be a pseudo-Riemannian manifold and Y a totally geodesic hypersurface $Y \subset X$.

We describe all linear differential operators $\mathcal{E}^i(X) \to \mathcal{E}^j(Y)$ between the spaces of differential forms that intertwine multiplier representations of the Lie algebra of conformal vector fields in the setting where both X and Y are of constant sectional curvature, illustrated by the examples of anti-de Sitter spaces and hyperbolic spaces.

44. **Jakub REMBIELIŃSKI** – *Uniwersytet Łódzki, Poland*

Title to be announced

45. **Mikołaj ROTKIEWICZ** – *Warsaw University, Poland*

Higher algebroids via differential relations

We introduce the concept of a higher algebroid, naturally generalizing the notions of an algebroid and a higher tangent bundle. Our ideas are based on a description of (Lie) algebroids as Zakrzewski morphisms — differential relations of a special kind. In our approach higher algebroids are Zakrzewski morphism between graded-linear bundles satisfying natural axioms. We provide natural examples and discuss applications in geometric mechanics. (joint work with Michał Jóźwikowski)

46. **Sutanu ROY** – *National Institute of Science Education and Research, India*

Braided quantum group structure on quantum plane

Semidirect product of groups is equivalent to a group with an idempotent endomorphism. Quantum analogue of this result says that every braided quantum group is equivalent to a quantum group with a projection. In this talk we shall discuss braided quantum structure of the quantum plane over the group of circle, and show that the ambient quantum group with projection coincides with Woronowicz's (simplified) Eq(2) group.

47. **Nasrin SADEGH ZADEH** – *University of Qom, Iran*

On Spherically Symmetric Finsler metrics

In this paper, we study spherically symmetric Finsler metrics in R^n with quadratic curvatures. We find equations that characterize the metrics of R-quadratic, and Ricci-quadratic types. We give a lot of new Finsler metrics of R-quadratic type which are non-trivial.

Spherically symmetric space-times are so important to study of general relativity. The Schwarzschild metric in four dimensional space-time is a solution of the vacuum Einstein field equations that describes the spherically symmetric gravitational field. In Riemannian geometry these special spaces have been deeply studied by many authors for example, [6] and [14]. The base of general relativity is (pseudo-) Riemannian geometry, it is natural to consider its generalizations based on Finsler geometry. In fact Finsler geometry have applications in physics, too [1].

Similarly with the definition in general relativity, a spherically symmetric Finsler metric is invariant under any rotations in R^n. In other words, the vector fields generated by rotations are the Killing fields of the Finsler metric. In calculation point of view the Finsler metrics with certain symmetry would greatly simplify the computation. Recently many papers has been published investigating the properties of these metrics, for example [16], [17] and [5]. Riemann curvature is a central concept in Riemannian geometry and was introduced by Riemann in 1854. Berwald generalized it to Finsler metrics. A Finsler metric is said to be R-quadratic if its Riemann curvature is quadratic [4]. R-quadratic metrics were first introduced by Báscó and Matsumoto [2]. They form a rich class in Finsler geometry. There are many interesting works related to this subject [12], [15]. In this paper we are going to study R-quadratic spherically symmetric Finsler metrics in R^n. The necessary and sufficient conditions which the metrics be R-quadratic are considered. Ricci-quadratic spherically symmetric Finsler metrics in R^n are studied, too. In particular, we show that non-Riemannian R-quadratic spherically sym- metric Finsler metrics in R^n are R-flat ($R^i_k = 0$).

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48. **Franklin SCHROECK** — *University of Denver, United States*

Classical Statistical and Quantum Mechanics on Phase Space

We will review and expand on what we said in this conference years ago — that many of the problems associated with quantum mechanics in the 1927-1950 period were pointed out by many first rate physicists and mathematicians, but that the problems have remained all this time. Now, with classical statistical mechanics and quantum mechanics on phase space firmly established by methods of Lie group theory, we first review the mathematics behind it and point out how this allows us to resolve all the problems with the usual quantum mechanics. Then we show that the resulting theory has real applications (that in many cases are simpler) in many areas in physics. Although the theory applies to all areas of physics, including Galilean, Poincaré, and de Sitter physics and to quantum field theory as well, we confine this discussion to physics on the Heisenberg group as an illustration of the richness and novelty of the theory. We will show that it has many applications to the philosophy of science that are new but quite reasonable. See also the talk by Prof. Roberto Beneduci on this subject.

49. **Armen SERGEEV** — *Steklov Mathematical Institute, Russia*

Non-smooth strings and noncommutative geometry

The phase manifold of d-dimensional theory of smooth closed strings may be identified with the space $\Omega(R_d)$ of smooth loops taking values in the d-dimensional Minkowski space R_d. However, the symplectic form ω of this theory can be extended to the Sobolev completion of $\Omega(R_d)$ given by the space $V_d = H_0^{1/2}(S^1, R_d)$ of half-differentiable loops with values in R_d. The group of reparametrizations of such strings coincides with the group $\mathrm{QS}(S^1)$ of quasisymmetric homeomorphisms of the circle and its action on the Sobolev space V_d preserves the symplectic form ω. Taking this into account it is natural to choose for the phase manifold of the theory of non-smooth strings the space V_d provided with the action of the group $\mathrm{QS}(S^1)$. If this action would be smooth we could associate with this theory a classical system consisting of the phase manifold V_d and the Lie algebra of the group $\mathrm{QS}(S^1)$. However, this action is not smooth and we cannot associate any classical Lie algebra with the group $\mathrm{QS}(S^1)$. Nevertheless, we can construct a quantum Lie algebra associated with V_d. We use for that an approach based on the Connes noncommutative geometry.

50. **Andrei SHAFAREVICH** — *Moscow State University, Russia*

Differential equations on polytopes: Laplacians and Lagrangian manifolds, corresponding to semi-classical motion

We study differential operators and corresponding evolution equations on polytopes. We describe kernels of the Laplacians and Lagrangian manifolds, correponding to semi-classical motion.

51. **Kalyan Bidhan SINHA** — *J.N. Centre for Advanced Scientific Research, India*

Spectral Analysis of Semibounded Operators by truncation

Arveson's program of numerical spectral analysis of bounded operators is extended to semibounded self-adjoint operators in an infinite-dimensional Hilbert space. The idea of quasi-diagonalisation of Weyl–von Neumann plays an important role in the analysis. This is part of a joint work with M. Namboodiri.

52. **Andrzej SITARZ** — *Jagiellonian University, Poland*

Decompactifying the fuzzy sphere

I'll present the method to compactify Moyal plane to obtain a Moyal sphere and decompactify the fuzzy sphere to obtain a fuzzy approximation of the plane (and possibly hyperbolic space).

53. **Daniel STERNHEIMER** — *Rikkyo University / Université de Bourgogne, France*

The reasonable effectiveness of mathematical deformation theory in physics

54. **Marzena SZAJEWSKA** — *Uniwersytet w Białymstoku, Poland*

Non-crystallographic branching rules

Reduction of orbits of finite reflection groups to their reflection subgroups is presented.

55. **Jaromir TOSIEK** — *Łódź University of Technology, Poland*

States over the *-algebra of formal series

Several classes of continuous linear functionals over different algebras applied in classical and quantum physics are introduced. The notion of positivity in formal series calculus is proposed. Problems with defining quantum states over the set of formal series are analysed.

56. **Elizaveta VISHNYAKOVA** — *Universidade Federal de Minas Gerais, Brazil*

Geometrization of graded manifolds of type Δ

Vector bundles and double vector bundles, or 2-fold vector bundles, arise naturally for instance as base spaces for algebraic structures such as Lie algebroids, Courant algebroids and double Lie algebroids. It is known that all these structures possess a unified description using the language of supergeometry and graded manifolds of degree ≤ 2. Indeed, a link has been established between the super and classical pictures by the geometrization process, leading to an equivalence of the category of graded manifolds of degree ≤ 2 and the category of (double) vector bundles with additional structures.

Our talk is devoted to the geometrization process in the case of $\mathbb{Z}^r$-graded manifolds of type Δ, where Δ is a certain weight system and r is the rank of Δ. We establish an equivalence between a subcategory of the category of n-fold vector bundles and the category of graded manifolds of type Δ.

57. **Elmar WAGNER** — *Michoacan University, Mexico*

Dirac operator on a noncommutative Toeplitz torus

We present an even spectral triple on a noncommutative torus defined as a subalgebra of the Toeplitz algebra. This spectral triple has spectral dimension 1, so one can say that the Toeplitz deformation results in a "dimension drop" of the noncommutative torus. This dimension drop will be discussed in the talk. (Joint work with Fredy Diaz.)

58. **Akira YOSHIOKA** — *Tokyo University of Science, Japan*

Star product and star exponential

A star product is a binary product for certain functions on $\mathbb{R}^n$ or $\mathbb{C}^n$. Here star product is given in non-formal sense. While star products are non-commutative in general, some star products are commutative.

We give a brief review on star products. We introduce star products for certain function space. In its algebra we consider exponential elements, which are called star exponentials. Using star exponentials we construct star functions. The talk is not general, instead we explain using concrete examples.

This talk is based on the joint work with H. Omori, Y. Maeda, N. Miyazaki.

Poster session

59. **Emmanuel BOURRET** — *Université de Montréal, Canada*

Dynamical generation of graphene

60. **Pierre-Henry COLLIN** — *University of Lorraine, France*

Explicit description of K-theory of Penrose hyperbolic tilings

One can construct hyperbolic tilings of Penrose type using substitution on the real line. I will explain how we can describe precisely K-theory and furthermore the generators of those groups using groupoids C^*-algebras and Morita equivalence.

61. **Tomasz CZYŻYCKI** — *Uniwersytet w Białymstoku, Poland*

Eight kinds of orthogonal polynomials of Weyl group C2 and tau method

We present eight types of orthogonal polynomials generated by orbit functions of the Weyl group C2 including four non-standard types obtained by an admissible weight shift. The discrete orthogonality relations of the studied polynomials on generalized Chebyshev nodes corresponding to shifted lattices are formulated. We also discuss the utilization of these two-variable polynomials in the tau method for the approximation of solutions of differential equations. Joint work with Jiří Hrivnák.

62. **Zofia GRABOWIECKA** — *Université de Montréal, Canada*

Subsymmetry decomposition of H_3 polytopes

63. **Grzegorz JAKIMOWICZ** — *Uniwersytet w Białymstoku, Poland*

Factorization method applied to the second order difference equations

The factorization method offers the possibility of finding solutions of new classes of difference equations. We show how to integrate certain classes of second order difference equations. Finally, an example is presented to illustrate our main result.

This is a joint work with Alina Dobrogowska.

64. **Andrey KRUTOV** — *Polish Academy of Sciences, Poland*

On integrability of new fifth order $N = 1$ supersymmetric evolution equation

We discuss integrability properties of recently discovered fifth order $N = 1$ supersymmetric evolution equation. Namely, we construct its $sl(2|1)$-valued zero-curvature representation (ZCR) with non-removable parameter via cohomological techniques.

65. **Petr NOVOTNÝ** — *Czech Technical University in Prague, Czech Republic*

Contractions and Invariants of Lie algebras

Invariant characteristics of Lie algebras are used for classification of Lie algebras as well as for classification of their contractions. The set of known invariant characteristics together with their behavior with respect to contractions is reviewed and extended by a new set of invariants. These are obtained from cohomology cocycles. Complex Lie algebras of finite dimension are considered only.

66. **Shahriar SALIMI** — *University of Kurdistan, Iran*

Entropic uncertainty relation with quantum memory

Heisenberg's uncertainty principle sets a lower bound on the uncertainties of two incompatible observables measured on a particle. The uncertainty lower bound can be reduced by considering a particle as a quantum memory correlating with the measured particle. Beside fundamental importance, the lower bound of entropic uncertainty relation in the presence of quantum memory has various applications, ranging from entanglement detection to quantum cryptography. In this paper, we obtain a lower bound for the entropic uncertainty in the presence of quantum memory which is tighter than the previous lower bounds. Also, we consider a tripartite scenario in which an entangled quantum state has been shared among Alice, Bob, and Charlie. Bob and Charlie want to know the Alice's measurement outcomes. Because of entanglement monogamy, no one can guess Alice's measurement outcomes exactly. So, they concentrate their correlation with Alice in Charlie's side by local operations and classical communication. By this strategy, Charlie can guess the Alice's measurement outcomes with better accuracy. We obtain a lower bound for Charlie's uncertainty about Alice's measurement outcomes after concentrating information and compare it with the lower bound without concentrating information in some examples.

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