XLII WORKSHOP ON GEOMETRIC METHODS IN PHYSICS

Białystok, Poland

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WYDZIAŁ MATEMATYKI

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LIST OF ABSTRACTS

Plenary lectures

1. **Ricardo CORREA DA SILVA** — *FAU Erlangen-Nürnberg, Germany*

   Twisted Araki–Woods Algebras: structure and inclusions

   We will introduce the family $\mathcal{L}_T(H)$ of von Neumann algebras with respect to the standard subspace H and the twist $T \in B(\mathcal{H} \otimes \mathcal{H})$ known as T-twisted Araki–Woods algebras, which are interesting in Algebraic Quantum Field Theory. These algebras encode localization properties in the standard subspace and provide a general framework of the Bose and Fermi second quantization, the S-symmetric Fock spaces, and the full Fock spaces from free probability. Under the assumption of compatibility between T and H, we are going to present the equivalence between T satisfying a standard subspace version of crossing symmetry, and the Yang–Baxter equation (braid equation) and the Fock vacuum being cyclic and separating for $\mathcal{L}_T(H)$.

   Under the same assumptions above, we also determine the Tomita–Takesaki modular data for Araki–Woods algebra and the Fock vacuum, and study the inclusions $\mathcal{L}_T(K) \subset \mathcal{L}_T(H)$ of such algebras and their relative commutants for standard subspaces $K \subset H$.

   This talk is based on a joint work with Gandalf Lechner (arXiv: 2212.02298).

2. **Rita FIORESI** — *Università di Bologna, Italy*

   Geometric Deep Learning meets Quantum Groups: a quantum differential calculus approach to differential geometry on graphs for machine learning

   The recent advancements in machine learning have prompted interest in discrete differential geometry. In this talk we present some state of the art techniques as sheaf neural networks in geometric deep learning and their interpretation via quantum differential calculus and quantum principal bundles, together with the quantum notions of connection and curvature.

3. **Volodymyr MAZORCHUK** — *Uppsala University, Sweden*

   Infinite Dynkin diagrams and monoidal actions in Lie-theoretic context

   Dynkin diagrams, both finite and infinite, are combinatorial gadgets which are used in many areas of modern mathemtics. In particular, they appear in classification of various objects related to the monoidal category of finite dimensional representations of the Lie algebra sl_2 and its quantum analogue. In this talk I will discuss some classical examples as well as certain sl_n-generalizations.

4. **Vincenzo MORINELLI** — *Tor Vergata University of Rome, Italy*

   From local nets to Euler elements

   The interplay between geometric and algebraic structures in Algebraic Quantum Field Theory (AQFT) has long been a rich field of study, drawing insights from operator algebras, Lie theory, category theory, and other areas of mathematics. An important theme in AQFT is understanding how the localization properties and the properties of local algebras of quantum fields are tied to the underlying geomet ry of the models. In recent joint work with K.-H. Neeb (University of Erlangen-Nürnberg), we have studied this relationship through the Lie theory language, to generalize geometric-algebraic correspondences within AQFT. We will discuss the deep relationship between the geometry of standard subspaces, the geometry of Euler elements in the Lie algebra of a Lie group and the geometry of an Algebraic Quantum Field Theory. We will also present the construction and the properties of new geometric models that we have developed within a generalized framework for AQFT.

   Based on the joint work [1] with K.-H.

References

[1] V. Morinelli, K.-H. Neeb, From local nets to Euler elements. Adv. Math. 458, p.109960, 2024 DOI: 10.1016/j.aim.2024.109960.

5. **Philip MORRISON** — *University of Texas at Austin, USA*

Metriplectic Geometries: Definitions and Applications

Metriplectic dynamics is a kind of dynamical system (finite or infinite) that ensures thermodynamic consistency: conservation of energy and production of entropy. It is based on the metriplectic 4-bracket that maps four phase space functions to another, and has the algebraic curvature symmetries. Metriplectic 4-brackets can be constructed using the Kulkarni–Nomizu product or via a pure Lie algebraic formalism based on the Koszul connection. The formalism produces many known and new dynamical systems. It also provides a pathway for constructing structure preserving numerical algorithms. Recent papers are below:

References

[1] P. J. Morrison, M. Updike, "Inclusive Curvature-Like Framework for Describing Dissipation: Metriplectic 4-Bracket Dynamics," Physical Review E 109, 045202 (22pp) (2024) DOI: 10.1103/PhysRevE.109.045202.

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[4] W. Barham, P. J. Morrison, A. Zaidni, "A thermodynamically consistent discretization of 1D thermal-fluid models using their metriplectic 4-bracket structure," arXiv: 2410.11045v2 19 Oct 2024.

[5] A. Zaidni, P. J. Morrison, "Metriplectic 4-bracket algorithm for constructing thermodynamically consistent dynamical systems," arXiv: 2501.00159v1 30 Dec 2024.

6. **Réamonn Ó BUACHALLA** — *Charles University, Czech Republic*

Levi-Civita Connections for the Irreducible Quantum Flag Manifolds

In the 2000s a series of seminal papers by Heckenberger and Kolb introduced an essentially unique covariant q-deformed de Rham complex for the irreducible quantum flag manifolds. In the years since, it has become increasingly clear that these differential graded algebras have a central role to play in understanding the noncommutative geometry of the Drinfeld–Jimbo quantum groups. In this talk we present the recent classification of covariant Levi-Civita metrics (in the sense of Beggs and Majid) for these differential calculi. Moreover, we will show how the bimodule map of these connections allows us to understand the Heckenberger–Kolb calculi as quantum exterior algebras. Time permitting, we will discuss the extension of this work to the full quantum flag manifolds.

7. **Alexander SMITH** — *Saint Anselm College / Dartmouth College, USA*

Time observables, relational dynamics, and quantum time dilation

General relativity demands that spacetime not be treated as a fixed background structure but as a dynamical entity. In the canonical formulation, this manifests as a Hamiltonian constraint, which appears to "freeze" physical states and gives rise to the notorious problem of time in quantum gravity: if the total Hamiltonian annihilates all states of matter and geometry, how does our familiar notion of time evolution emerge? In this talk, I will review a class of time observables described by covariant positive-operator-valued measures (POVMs) [1]. These POVMs evade Pauli's objection to the existence of a time operator, saturate the time-energy uncertainty relation, and serve as the keystone for two equivalent formulations of relational quantum dynamics [2, 3, 4, 5]:

(a) The Page–Wootters formalism, in which evolution is encoded in entanglement between a clock and the rest of the system;

(b) The evolving constants of motion formalism, in which a family of gauge-invariant Dirac observables is constructed that evolve relationally with respect to a chosen clock variable.

Using these formalisms, I will show how dynamics emerges from conditional probabilities and the kinematical structure of quantum theory alone [3]. I will also outline extensions to interacting clock systems [2] and quantum field theory [6]. Finally, I will apply this machinery to relativistic particles carrying internal degrees of freedom that function as clocks measuring their proper time [7]. Remarkably, a novel quantum time-dilation effect arises between two clocks when one is placed in a superposition of different momenta or a superposition of locations in a gravitational field. Using the lifetime of a hydrogen-like atom as a concrete clock, I will argue that this effect is within reach of current high-precision spectroscopic experiments, thus offering a new test of relativistic quantum mechanics [8, 9]. Moreover, by invoking the Helstrom–Holevo bound, I will derive a fundamental time-energy uncertainty relation linking the precision of proper-time measurements to the clock's rest mass [7].

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[2] Smith, A.R.H. & Ahmadi, M. Quantizing time: Interacting clocks and systems. Quantum 3, 160 (2019). DOI: 10.22331/q-2019-07-08-160

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[9] Paczos, J., Dębski, K., Grochowski, P.T., Smith, A.R.H. & Dragan, A. Quantum time dilation in a gravitational field. Quantum 8, 1338 (2024). DOI: 10.22331/q-2024-05-07-1338

8. Alice Barbara TUMPACH — *Wolfgang Pauli Institut, Austria*

The restricted Grassmannian and its cotangent space from various points of view

This talk is divided into two parts. First, the construction of the restricted Grassmannian as symplectic and Kähler quotient is revisited in the language of frame theory. In this context, the set of k-tight frames which are unitary equivalent for the Hilbert–Schmidt norm to a fixed k-tight frame corresponds to a level set of the momentum map. In the second part of the talk we "double" the dimension and construct the cotangent space of the restricted Grassmannian as a tri-symplectic and hyper-Kähler quotient. The diffeomorphism between the cotangent space of the restricted Grassmannian and the complexification of the restricted Grassmannian following from Mostow's decomposition theorem will be explained. The Kähler potentials for various complex structures will be given. This talk is based on a joint work with T. Goliński, T. Needham and C. Shonkwiler.

Contributed lectures

1. **Naveena Kumara ATHITHAMOOLE** — *Ruđer Bošković Institute, Croatia*

   Dirac Quasinormal Modes in Noncommutative Reissner–Nordström Black Holes

   Noncommutative (NC) geometry provides a novel approach to probe quantum gravity effects in black hole spacetimes. This talk explores Dirac quasinormal modes (QNMs) in a deformed Reissner–Nordström (RN) black hole, where noncommutativity induces an effective metric with an additional ($r - \phi$) component. Employing a semiclassical model equivalent to a noncommutative gauge theory, we investigate the dynamics of massless Dirac fields and calculate their QNM frequencies using the continued fraction method, enhanced by Gauss elimination to address six-term recurrence relations. Our results demonstrate notable shifts in oscillation frequencies and damping rates relative to the commutative RN case, exhibiting a distinctive Zeeman-like splitting in the QNM spectrum driven by the noncommutative parameter. These findings highlight the impact of spacetime noncommutativity on black hole spectroscopy and provide insights into quantum gravity signatures potentially observable in gravitational wave signals.

2. **Paul-Hermann BALDUF** — *University of Oxford, Mathematical Institute, United Kingdom*

   Topological quantum field theory and the odd graph complex

   Recent articles by Davide Gaiotto and collaborators resulted in a new setup for parametric Feynman integrals in topological quantum field theories. In arXiv: 2408.03192, joint with Davide Gaiotto, we developed a description of these integrands in terms of standard graph polynomials, and used it to give a new proof for the Kontsevich formality theorem. My talk will focus on the recent result arXiv: 2503.09558, together with Simone Hu, that this "topological" integral coincides with an integral that had been used in cohomology computations of the odd graph complex and of GL_n by Francis Brown and collaborators. This relation implies a very elegant description of the topological integrand in terms of the Pfaffian of a Laplacian matrix, and yet another proof of the Kontsevich formality theorem.

3. **Krzysztof BARDADYN** — *University of Białystok, Poland*

   On the Banach–Lamperti Theorem

4. **Alessandro CAROTENUTO** — *Università di Parma, Italy*

   Convex orderings on positive roots and quantum tangent spaces

   In noncommutative differential geometry the information on the differential structure of a noncommutative space is encapsulated in the choice of a first order differential calculus. In the case of quantum homogeneous spaces, this is equivalent to giving the choice of a so-called quantum tangent space. In a recent work of Ó Buachalla and Somberg, it was proposed that quantum tangent spaces for quantum flag manifolds can be derived from the theory of PBW basis of quantized enveloping algebras defined by Lusztig. This depends in turn on the choice of a reduced decomposition of the longest element w_0 of the Weyl group. In this talk, based on a collaboration with C. Hohlweg and P. Papi, I will show the combinatorial conditions under which a reduced decomposition of w_0 gives rise to a quantum tangent space.

5. **Goce CHADZITASKOS** — *Czech Technical University in Prague, Czech Republic*

   Parabolic cylinder functions as orthonormal bases on $L^2(\mathbb{R}^+)$ and $L^2(\mathbb{R})$

   In addition to orthogonal polynomials, orthogonal functions also play an important role and have a wide range of uses. They are related to the solution of differential equations. In this contribution we present the explicit form of one parameter families of orthonormal bases on spaces $L^2(\mathbb{R}^+)$ and $L^2(\mathbb{R})$. The bases are formed by eigenvectors of the self-adjoint extension of Schrödinger operator of the asymmetric harmonic oscillator. For each parameter the set of eigenvectors form an orthonormal basis on $L^2(\mathbb{R}^+)$ or $L^2(\mathbb{R})$. The Hermite polynomials are done by special parameters.

6. **Jen-Hsu CHANG** — *National Defense University, Taiwan*

Construction of totally non-negative pfaffian

The totally non-negative Pfaffians are introduced via the Tau-function of the B-Type Kadomtsev–Petviashvili Equation (BKP) equation to obtain non-singular line-solitons solution. The line solitons interact to form web-like structure in the near field region and their resonances appearing in soliton graph. One studies the construction of totally nonnegative pfaffian using the perfect matchings of plane graph with $2n$ vertices appearing in cyclic order on a face. Also, the relations with the chord diagrams are discussed.

7. **Tomasz CZYŻYCKI** — *University of Białystok, Poland*

Nonlinear superposition principle for Riccati equation

It is well known that linear combination of solutions represent a new solution of a linear system of algebraic equations as well as differential or difference ones. For nonlinear equations it is not true but in some cases we can find nonlinear principle of superposition, it means nonlinear formula which allows to compose some known solutions and obtain a new solution. In this talk we present examples of such principle, especially for scalar Riccati equation in general form, connections with group theory and applications in mathematical physics problems.

8. **Alina DOBROGOWSKA** — *University of Białystok, Poland*

Cyclic Lie–Rinehart algebras

We study Lie–Rinehart algebra structures in a framework provided by duality pairings of modules over unital commutative associative algebra. Thus, we construct new examples of Lie brackets corresponding to a fixed anchor map whose image is a cyclic submodule of the derivation module, and therefore we call them cyclic Lie–Rinehart algebras. Special cases of our construction include Lie algebroid structures on cotangent bundles of differential manifolds and also certain differential operators that occur in mathematical physics.

9. **Fatih ERMAN** — *İzmir Institute of Technology, Turkey*

On the Completeness of Energy Eigenfunctions for Renormalized Quantum Systems

We consider Hamiltonians of the form $H_0 - \alpha\delta_a$ in two or three dimensions, where δ_a is the delta function supported at a point a, and the spectrum of H_0 contains only discrete spectrum, which is bounded from below. For instance, H_0 could be the harmonic oscillator Hamiltonian or free Hamiltonian for a particle moving intrinsically on a $D = 2, 3$ dimensional compact manifold with $Ric_g(\cdot,\cdot) \geq (D-1)\kappa g(\cdot,\cdot)$. We first summarize the formula for the resolvent (or Green's function, which is the integral kernel of resolvent) by the renormalization procedure. Then, we give an argument about how the pole structure of the full Green's function $G(x, y|E)$ is rearranged to form new poles and how the poles of $G_0(x, y|E)$ are removed in general. We then give the proof of the orthonormality and completeness of the eigenfunctions of the Hamiltonian by using a contour deformation in the complex energy plane under the assumption that H_0 has the complete set of eigenfunctions. This will allow us to write the Hamiltonian operator explicitly as an integral operator after the renormalization procedure. The complete set of eigenfunctions ensures that the resulting Hamiltonian is essentially self-adjoint. We finally discuss one interesting application of this explicit formula, where the support of the delta function is suddenly changed. This is a joint work with O. Teoman Turgut.

10. **Ümit ERTEM** — *Diyanet İşleri Başkanlığı, Turkey*

Hidden symmetries and their algebra structures on Courant algebroids

Hidden symmetries are higher degree antisymmetric generalizations of Killing vector fields that correspond to isometries of the ambient manifold. We generalize the definitions of Killing vector fields in Courant algebroids to the hidden symmetries by using the definitions of Lie derivatives and connections on Courant algebroids. We show that the structure of hidden symmetries are similar to the hidden symmetries in the presence of torsion. We also investigate the Lie algebra structures of hidden symmetries with torsion to generalize the results to the framework of Courant algebroids.

11. **Laszlo FEHER** — *University of Szeged / Wigner RCP, Budapest, Hungary*

Integrable systems from Poisson reductions of generalized Hamiltonian torus actions

First, we develop sufficient conditions for guaranteeing that an integrable system with symmetry group K on a manifold M descends to an integrable system on a dense open subspace of the quotient Poisson space M/K and on its symplectic leaves. Then, we present applications to reductions of master systems on cotangent bundles and Heisenberg doubles of compact Lie groups and to integrable systems on moduli spaces of flat connections. In almost all examples, the term 'integrability' refers to degenerate integrability, alias superintegrability. The talk is based on a joint paper with Maxime Fairon.

12. **David J. FERNANDEZ C.** — *CINVESTAV, Mexico*

Confluent supersymmetric algorithm for bilayer graphene

External magnetic fields leading to equidistant and partially equidistant spectra for bilayer graphene are generated through the integral and differential versions of the confluent second-order supersymmetric quantum mechanics applied to the harmonic oscillator. The Barut–Girardello and Gilmore–Perelomov coherent states for bilayer graphene are as well derived. Their evolution is analyzed, identifying cases for which time stability and cyclic evolution arise. The geometric phase and uncertainty product of the quadratures for such coherent states are as well studied.

13. **Manuel GADELLA** — *University of Valladolid, Spain*

Rigged Hilbert Spaces: A Contribution in Honor of Arno Bohm

Rigged Hilbert Spaces (RHS), also called Gelfand triplets, have been useful in order to give rigorous mathematical meaning to some aspects of the Dirac formulation of Quantum Mechanics that remain unexplained under the Hilbert space formulation, as Arno Bohm first realized. In this talk one refers to some aspects of the spectral decomposition of self adjoint operators under the perspective of RHS and show how RHS give a unified account of (Gelfand) continuous and discrete basis, special functions and representations of symmetry Lie algebras with continuous operators.

14. **Jean-Pierre GAZEAU** — *University of Białystok, Poland*

A purely geometrical Aharonov–Bohm effect

I will present an application of affine covariant integral quantization (ACIQ) to quantum mechanics on the punctured plane. The associated four-dimensional phase space is identified with the similitude group $SIM(2)$, which encodes translations, rotations, and dilations of the plane. Due to the topology of the punctured plane, our quantization procedure gives rise to an affine vector potential. This potential can be interpreted as the Aharonov–Bohm (AB) gauge field produced by an infinite solenoid. This observation supports a reinterpretation of the AB effect: it emerges from the topological constraint imposed by the impenetrable coil rather than from an externally applied classical gauge field. In addition to this gauge structure, ACIQ also generates a repulsive, centrifugal-like scalar potential, a feature already encountered when applying ACIQ to motion on the half-line, whose phase space is the open half-plane. These results provide a new perspective on the AB effect, highlighting the central roles of topology and symmetry in quantum mechanics.

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15. **Gerald GOLDIN** — *Rutgers University, USA*

The Kinematics of Anyon Multipole Configurations

In two space dimensions, we show how interesting quantum phases can arise not only from the exchange statistics of anyons, but independently from their theoretically possible internal structure. I will discuss the possible kinematics of anyon configurations having dipole and quadrupole properties. This is in collaboration with Hongyi Shen at Rutgers University, and forms part of his Ph.D. thesis in progress.

16. **Tomasz GOLIŃSKI** — *University of Białystok, Poland*

Nijenhuis operators on Banach homogeneous spaces

For a Banach–Lie group G and an embedded Lie subgroup K we consider the homogeneous Banach manifold $\mathcal{M} = G/K$. In this context, we establish the most general conditions for a bounded operator N acting on $Lie(G)$ to define a homogeneous vector bundle map $\mathcal{N} : T\mathcal{M} \to T\mathcal{M}$. In particular, our considerations extend all previous settings in the matter and are well suited for the case where $Lie(K)$ is not complemented in $Lie(G)$. We show that the vanishing of the Nijenhuis torsion for $\mathcal{N}$ (defined by an admissible bounded operator N on $Lie(G)$) is equivalent to the Nijenhuis torsion of N having values in $Lie(K)$. As an application, we consider the question of the integrability of an almost complex structure $\mathcal{J}$ on $\mathcal{M}$ induced by an admissible bounded operator J, and we give a simple characterization of the integrability in terms of certain subspaces of the complexification of $Lie(G)$. Some examples related to C^*-algebras will be presented.

This is a joint work with G. Larotonda and A.B. Tumpach.

17. **Pavel HOLBA** — *Silesian University in Opava, Czech Republic*

Conservation laws for Extended Generalized Cahn–Hilliard–Kuramoto–Sivashinsky Equation in Any Dimension

We present a complete characterization of nontrivial local conservation laws for the extended generalized Cahn–Hilliard–Kuramoto–Sivashinsky equation in any space dimension. This equation naturally generalizes the well-known and widely used Cahn–Hilliard and Kuramoto–Sivashinsky equations, which have manifold applications in chemistry, physics, and biology. In particular, we demonstrate that any nontrivial local conservation law of any order for the equation under study is equivalent to a conservation law whose density is linear in the dependent variable with the coefficient at the dependent variable depending only on the independent variables.

For further details please see the paper [1].

References

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18. **Yasushi IKEDA** — *Sapporo, Japan*

Quantum argument shift method for the universal enveloping algebra $U\mathfrak{gl}_n$

The argument shift method is a technique for constructing Lie–Poisson maximal commutative subalgebras (argument shift subalgebras) of the symmetric algebra $S(\mathfrak{g})$ of a Lie algebra $\mathfrak{g}$. The quantizations of these subalgebras—known as quantum argument shift subalgebras—are maximal commutative subalgebras of the universal enveloping algebra $U(\mathfrak{g})$ and play a fundamental role in quantum integrable systems. Although their existence and uniqueness have been established in many cases, the argument shift procedures themselves remained unquantized. Last year, Georgy Sharygin and I defined quantized argument shift procedures for the general linear Lie algebra $\mathfrak{gl}_n$ and proved that they generate the corresponding quantum argument shift subalgebras.

19. **Brian KENDRICK** — *Los Alamos National Laboratory, USA*

The Geometric Phase Controls Ultracold Chemistry

The unique properties of ultracold ($T < 1$ mK) atom-molecule collisions often lead to unprecedented quantum interference effects that effectively control the collision outcome. As the collision energy approaches absolute zero, the cross sections obey the Wigner threshold laws and the rate coefficients for barrierless exothermic reactions approach a constant (non-zero) value. Many of the molecules of experimental interest, exhibit a conical intersection (degeneracy) between the ground and first excited electronic states. This degeneracy gives rise to a $U(1)$ gauge potential analogous to that of a magnetic solenoid centered at the degeneracy. During the collision process, quantum interference occurs between the two components of the scattering wavefunction that encircle the conical intersection. In the ultracold regime, this interference can approach its maximal values (via Levinson's theorem) effectively acting as a quantum switch turning the reaction on or off. The geometric (Berry) phase associated with the conical intersection reverses the nature of the quantum interference (i.e., constructive becomes destructive and vice versa) and therefore gives the opposite theoretical prediction for the collision outcome relative to a calculation that ignores the phase. We will discuss all of these effects in detail and present results from accurate numerical quantum scattering calculations that demonstrate these effects for several molecular systems of experimental interest.

20. **Che-Ming KO** — *Texas A&M University, USA*

Wigner functions in heavy-ion Collisions

Among the many transformative contributions by Eugene Wigner to physics is the Wigner phase-space distribution function, which he introduced in 1932. Besides its extensive applications in quantum mechanics, statistical mechanics, quantum optics and information, and quantum chemistry etc., Wigner functions have also found applications in heavy ion collisions studied at the Heavy Ion Synchrotron at GSI, the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory, and the Large Hadron Collider (LHC) at CERN. These applications have helped understand the dynamics of heavy ion collisions and the mechanism of particle production from created hot dense matter. As a result, significant advances have been achieved in the determination of the properties of dense nuclear matter relevant for understanding the properties of neutron stars and their mergers, the properties of the quark-gluon plasma that existed soon after the big bang, and the dynamics of little bang nucleosynthesis. A brief review of these applications will be presented in this talk.

21. **Otto KONG** — *National Central University, Taiwan*

Noncommutative Geometry from the Perspective of Quantum Physics

The phase spaces of quantum physics have been appreciated as noncommutative symplectic geometry. Realizing Dirac's notion of q-numbers in a concrete manner, we have a picture of quantum mechanics as particle dynamics on a noncommutative geometric model of spacetime which we argue to be a candidate of the simplest noncommutative number manifold that could serve as the starting point to construct a geometric language for the geometries. Implications for a proper theory of quantum gravity will be discussed.

22. **Bartosz KWAŚNIEWSKI** — *University of Białystok, Poland*

Type semigroups and a dichotomy for groupoid C^*-algebras

Tarski developed the theory of type semigroups for group actions as a tool for studying phenomena such as the Banach–Tarski paradox. We discuss how to generalize this theory to groupoids. This allows us to achieve a dynamical version of dichotomy theorem for "classifiable" simple C^*-algebras — such C^*-algebras are either stably finite or purely infinite.

23. **Ali MOSTAFAZADEH** — *Koc University, Turkey*

On some recent developments in scattering theory: Fundamental transfer matrix and exactness of N-th order Born approximation

Potential scattering admits a formulation in terms of a fundamental notion of transfer matrix. This is a linear operator possessing a Dyson series expansion for an effective non-Hermitian Hamiltonian operator. This approach to potential scattering has so far led to several interesting developments. The most notable are the construction of the first examples of short-range potentials for which the N-th order Born approximation is exact, potentials that display broadband directional invisibility, and a singularity-free treatment of delta-function potentials lying on a line in two dimensions and on a plane in three dimensions. It has also been generalized to electromagnetic scattering and used to deal with certain electromagnetic radiation problems. This talk presents a brief review of these developments and addresses the mathematical problem of the existence of the fundamental transfer matrix within the context of propagating-wave approximation in two dimensions. This is an approximation scheme that ignores the contribution of the evanescent waves to the scattering amplitude and is valid for high energies and weak potentials. It becomes exact for a class of complex potentials. The latter includes an infinite subclass of potentials for which the N-th order Born approximation is exact with N depending on the frequency of the incident wave.

24. **Patrick MOYLAN** — *Pennsylvania State University, USA*

    Semisimple Groups and Associated Semi-Direct Products by Way of Examples: $SO_0(1,4)$, $SO_0(2,3)$ and the Poincaré Group

25. **Qian NIU** — *University of Science and Technology of China, China*

    Particle View in Crystals

    I will present a particle view of electrons in crystals based on semiclassical dynamics and describe how Berry curvatures modify thermodynamic and transport properties. I will then discuss more recent work on deformed crystals using a geodynamic language, and obtain Hall viscosity, flexsoelectric and flexsomagnetic responses. When the results are extended to 4d spacetime crystals, the geodynamics becomes greatly simplified and unified, allowing a fresh look of table-top general relativity.

26. **Anatolij PRYKARPATSKI** — *Cracow University of Technology, Poland*

    On the electron Hamiltonian, the mass term and its $SU(2) \times SU(2)$–gauge symmetry structure

    I present a novel description of the electron spin origin, its symmetry properties and related conservation laws from mathematical physics point of view, having put into background the algebraic description of the corresponding physically observed representations. There is analyzed in detail the spin structure and its crucial dependence on the $SU(2)$-symmetry properties of the related representations of the basic Clifford algebra, generated by creation-annihilation operators on the Fock space and the related chirality symmetry of the Pauli spin operators. Based on the conservation law of the spin projection on the electron momentum there is proposed a novel derivation of the Dirac Hamiltonian operator, whose Lorentz invariance is naturally related to that of the fundamental Maxwell equations, whose quanta are carriers of interaction between electrons. In this work we reanalyzed the electron spin origin in the framework both of representation of the related Clifford algebra of observable operators, generated by the electron creation-annihilation operators on the Fock space, and the electron mass problems from geometric point of view, based on the extended gauge group $(SU(2) \times SU(2)) \times U(1)$–symmetry, applied to the classical Standard Electromagnetic Model. It was demonstrated the existence of two types of $W^{\pm}$– and Z–boson particles, forming the electron mass, simultaneously producing no Higgs boson field.

    The report consists of the following chapters:

    1. Historical preliminaries
    2. Quantum electron spin states structure
    3. Quantum electron Hamiltonian derivation
    4. The electron mass within the gauge symmetry approach
    5. Conclusions and acknowledgements

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27. **Christoph PÜNTMANN** – *Head of Investment Consulting, Aon Pension Insurance Broker GmbH, Germany*

Ideas of physics in finance

28. **Stefan RAUCH** – *Linköping University, Sweden*

Dynamics of Jellet's Egg. Asymptotic solutions revisited

Jellett's egg (JE) is a rigid body having a shape of rotational ellipsoid with half-axes (a, b) where b is a symmetry axis. The center of the mass (CM) is shifted with respect to the geometric center O by distance $d = \kappa b < b$, $0 \le \kappa \le 1$ along b. The axes of main moment of inertia I_1, I_3 are aligned along the geometrical axes a, b. JE has an egg-like form for $a < b$, it looks like en elongated cigar when $a \ll b$ and for $b \ll a$ the JE looks like a button which becomes a flat disc when $b \to 0$.

It *rolls and slides* on the plane under the action of force of gravity, friction force and the reaction force of the supporting plane. When the JE is spun sufficiently fast, it displays behaviour similar to the tippe top (TT), its lower and heavier part may turn upside down so that the center of mass CM rises above the geometrical center O. Then JE spins for some time on the long edge before it falls down due to rotational friction and dissipation of kinetic energy. It is an effect that may be noted when one plays with a boiled egg on a kitchen table.

Physical parameters of both TT and JE have to satisfy certain geometrical and inertial conditions in order to display inversion under fast spinning initial conditions.

The main tool for studying the dynamical behaviour of a JE *rolling and sliding* in the plane is analysis of asymptotic/stationary solutions of equations of motion with friction and the conditions of reality for the asymptotic values of angular velocities ϕ_{JE}, ω_{3JE}.

The answer is that fast spinning JE inverts when parameters $\alpha = a/b$, $\gamma = I_1/I_3$ satisfy

a) geometric condition $1 - \kappa < \alpha^2 < 1 + \kappa$ and

b) inertial condition $1 - \kappa < \alpha^2\gamma < 1 + \kappa$.

For TT the a) condition is always satisfied as a=b so α=a/b=1 and b) condition becomes the known inequality $1 - \kappa < \gamma < 1 + \kappa$ when the whole range of tumbling solutions with $\theta \in (0, \pi)$ is admissible and the inversion is observed. This result is illustrated by numerical simulations of JE launched almost vertically with $\theta(0) = 1/10, 1/100$.

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29. **Wolfgang SCHLEICH** — *Institut für Quantenphysik Universität Ulm, Germany*

A geometrical approach towards the Riemann Hypothesis

30. **Sergei SHABANOV** — *University of Florida, USA*

Orbit space geometry in gauge systems and affine quatization

A method of constructing an explicitly gauge invariant symplectic structure is proposed. Its quantization automatically takes into account geometry of the physical configuration and phase spaces. The approach is a generalization of the affine quantization for configuration spaces with boundaries developed earlier by John Klauder. The method is illustrated with solvable examples of gauge systems in which the geometry of the physical configuration and phase spaces has a significant effect on the spectrum of the Hamiltonain.

31. **Piotr STACHURA** — *Warsaw University of Life Sciences, Poland*

Quantum spaces of lines

I will presents a differential groupoid with "coaction" of the groupoid underlying the Quantum Euclidean group (i.e. its C^*-algebra is the C^*-algebra of this quantum group). The dual of the Lie algebroid is a Poisson manifold that can be identified with the space of oriented lines in Euclidean space equipped with a Poisson action of the Poisson–Lie Euclidean group. Time permitting, I will also present a quantum space of timelike lines in Minkowski space. Based on arXiv: 2411.15977.

32. **Marzena SZAJEWSKA** — *University of Białystok, Poland*

A study of Casimir invariants in the context of the eigenvalue problem

In this talk, we propose a novel interpretation of Lie algebra invariants, with a particular focus on Casimir functions. The present study proposes an approach founded upon the established correlation between a linear mapping, herein designated F, and a predefined eigenvector, denoted v, within the context of a Lie algebra.

33. **Haydar UNCU** — *Turkish-German University, Turkey*

The harmonic oscillator potential perturbed by a combination of linear and non-linear Dirac delta interactions with application to Bose–Einstein condensation

In this study, we investigate the bound state analysis of a one dimensional nonlinear version of the Schrödinger equation for the harmonic oscillator potential perturbed by a δ potential, where the nonlinear term is taken to be proportional to $\delta(x)|\psi(x)|^2\psi(x)$. The bound state wave functions are explicitly found and the bound state energy of the system is algebraically determined by the solution of an implicit equation. Then, we apply this model to the Bose-Einstein condensation of a Bose gas in a harmonic trap with a dimple potential. We propose that the many-body interactions of the Bose gas can be effectively described by the nonlinear term in the Schrödinger equation. Then, we investigate the critical temperature, the condensate fraction, and the density profile of this system numerically.

34. **Josef ZWANZIGER** — *Dalhousie University, Canada*

The relationship between the Berry connection and orbital magnetism: First principles calculation of magnetic shielding

The modern theory of orbital magnetism as developed by Vanderbilt, Resta, Niu, and colleagues depends on the curvature of the Berry connection in the Brillouin zone of a solid. We describe this relationship, and show how we have used this approach to develop a practical implementation of the computation of magnetic shielding as measured in nuclear magnetic resonance spectroscopy.

Virtual contributed lectures

1. **Nathan HARSHMAN** — *American University, USA*

Geometric Phases and Exchange Statistics in One Dimension

In honor of Arno Bohm, I present some applications of geometrical phases to the topics of exchange statistics. Using the framework of Leinaas and Myrheim extended by the technology of orbifold fundamental groups, we find that anyon models in one dimension are well-defined, and I discuss recent realizations in experiments with ultracold atoms.

2. **Md Fazlul HOQUE** — *Pabna University of Science and Technology, Bangladesh*

Integrable and superintegrable classical systems in magnetic fields and Poisson algebras of their integrals of motion

The talk presents the construction of all nonstandard integrable systems in magnetic fields whose integrals have leading order structure that are elements of the universal enveloping algebra of the three-dimensional Euclidean algebra. We consider the natural Hamiltonian for a particle moving in the three dimensional Euclidean space

$$H(\vec{x},\vec{p}) = \frac{1}{2}\left(\vec{p}+\vec{A}(\vec{x})\right)^2 + W(\vec{x}),$$

where $\vec{p} = (p_1, p_2, p_3)$ are components of the linear momentum and $\vec{x} = (x_1, x_2, x_3) \equiv (x, y, z)$ the Cartesian spatial coordinates, $\vec{A}(\vec{x}) = (A_1(\vec{x}), A_2(\vec{x}), A_3(\vec{x}))$ is the vector potential depending on the position vector $\vec{x}$ and $W(\vec{x})$ is the electrostatic potential function involving only the coordinates $\vec{x}$. We choose the units in which the mass of the particle has the numerical value 1 and the charge of the particle is -1. The system assume to be integrable with a pair of integrals of motion X_1, X_2 which are quadratic polynomials in the momenta. The general form of the quadratic integrals of motion as

$$\begin{aligned} X_1 &= l_3^A p_3^A + a(p_1^A)^2 + b p_1^A p_2^A + \sum_{j=1}^{3} s_j(\vec{x}) p_j^A + m(\vec{x}), \\ X_2 &= (p_3^A)^2 + \sum_{j=1}^{3} S_j(\vec{x}) p_j^A + M(\vec{x}), \quad a, b \in \mathbb{R}, \end{aligned}$$

where the gauge covariant expressions were used, namely

$$p_i^A = p_i + A_i(\vec{x}), \quad l_i^A = \sum_{j,k=1}^{3} \varepsilon_{ijk} x_j p_k^A, \quad i = 1, 2, 3.$$

Here ε_{ijk} is the completely antisymmetric tensor with $\varepsilon_{123} = 1$. The functions $s_j(\vec{x})$, $S_j(\vec{x})$, $m(\vec{x})$ and $M(\vec{x})$ are to be determined by requiring that X_i, $i = 1, 2$ are commute with the Hamiltonian H as well as with each other. We show how these pairs of commuting elements lead to distinct independent integrals of motion in several nonvanishing magnetic fields. We also search for additional first- and second-order integrals of motion of these systems to arrive at superintegrable systems. We construct the corresponding Poisson algebras of integrals of motion. The separability of the systems are verified in various coordinates by the Levi-Civita condition. The talk is based on joint work with Libor Šnobl and Antonella Marchesiello, Czech Technical University in Prague, Czech Republic.

3. **Mahougnon Justin LANDALIDJI** — *Polytechnic University of San-Pedro, Ivory Coast*

   Kepler problem in the harmonic oscillator setting: recursion operator and relevant properties

   We study the Hamiltonian dynamics for the Kepler problem perturbed by a harmonic oscillator in parabolic coordinates. We derive the Hamiltonian vector fields describing the system evolution, and construct associated recursion operator generating the constants of motion. We then infer the existence of a bi-Hamiltonian structure, introduce master symmetries, and compute a family of conserved quantities.

4. **Jean-Pierre MAGNOT** — *LAREMA — Université d'Angers, France*

   Diffeological generalized formal series: an overview

   We gather here the existing results, published or pre-published separately, on the diffeoloies on formal series and their generalizations.

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

   The Dirac–Weyl equation in graphene

   Study of Wigner functions for massless Dirac fermions in a graphene layer lying on the xy-plane that interacts with an external homogeneous magnetic field $\vec{B} = B_0\hat{k}$ is presented. By solving the $\star_M$ Dirac–Weyl equation, the Landau levels as well as the Wigner functions for graphene electrons in the presence of magnetic field are obtained. The problem is considered on a discrete phase space.

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

   Convergent star product and application

   We consider star products for convergent power series on $\mathbb{C}^n$. In this talk, we give the definition of the star product and set the space where the star product converges. Convergent star product gives several non-trivial relations than formal star product, star products for formal power series with respect to the deformation parameter. We discuss some features of the convergent star product.

Poster presentations

1. **Grzegorz DZIEWISZ** — *University of Wrocław, Poland*

   Stochastic time delays from uncertainty relations in Doubly Special Relativity

   In the twentieth century, two foundational pillars of modern physics—quantum mechanics and the theory of relativity—were developed to describe nature at vastly different scales. Despite their individual successes, these theories remain fundamentally incompatible. One approach to unifying them is Deformed Special Relativity (DSR), which extends special relativity by introducing a second invariant scale, typically associated with the Planck energy. This deformation alters the structure of the Poincaré algebra and leads to a non-commutative geometry of spacetime. In this framework, the quantum nature of spacetime itself gives rise to modified uncertainty relations, reflecting the interplay between relativistic deformations and quantum fluctuations. My poster will focus on the origin and implications of these uncertainty relations, particularly how they emerge from non-commutative phase space and how stochastic noise—inherent to quantum processes in such a framework—may offer experimentally testable signatures. These insights contribute to ongoing efforts to probe the quantum structure of spacetime and test predictions of quantum gravity phenomenology.

2. **Grzegorz JAKIMOWICZ** — *University of Białystok, Poland*

   Poisson structure on predual of Banach Lie algebroid

   We construct the linear Poisson structure on the predual bundle of a Banach Lie algebroid. It is an alternative approach to the already known results on the linear sub-Poisson structure on the dual bundle. We also discuss the existence of queer Banach Lie algebroids. An example of a precotangent bundle is presented.

   This is joint work with T. Goliński.

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

   Title to be announced

4. **Severin POŠTA** — *Czech Technical University in Prague, Czech Republic*

   Realizations of sl(3)

   Although not honoured as one of the "fundamental group of physics", despite the Lie group SL$(3, \mathbb{C})$/SL$(3, \mathbb{R})$ and the associated Lie algebra play an important role in the symmetries of ordinary differential equations. It is therefore worthwhile to have realizations of this algebra in reserve in the case they are needed. In this contribution, we will be interested in how the realizations of sl(3) calculated by Shirokov's method look like when using the classification of sl(3)-subalgebras up to inner automorphism, which is known thanks to Douglas and Repka.

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