THE XII. INTERNATIONAL SYMPOSIUM ON QUANTUM THEORY AND SYMMETRIES

A B S T R A C T S

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PLENARY SPEAKERS

Twisted symmetries of dynamical systems and Poisson algebras

Cardona, Alexander

Departamento de Matemáticas, Universidad de los Andes, Colombia

In this talk we will show how the definition of Poisson algebras associated to twisted Dirac structures on smooth manifolds, on the one hand, and the description of T-duality as a duality of Lie algebroids, on the other hand, use the same type of geometric constraint imposed by a 3-form background. Particular examples of dynamical systems in which each one of these instances appear will be presented.

Discourse on Hadronic Formulae

Catto, Sultan

CUNY Graduate School and The Rockefeller University, New York, USA

We will explore the evolution of hadronic mass formulae, emphasizing group theoretical descriptions based on split-octonion algebra and "dynamical supersymmetry" suggested by QCD and based on diquark-antiquark symmetry.

Integrability, spacetime dynamics and field theories

Correa, Francisco

Universidad Austral de Chile, Casilla 567, Valdivia, Chile

In this talk I will review some recent developments connecting integrable models, gravitation, soliton theory and field theories. The relationship between the AKNS hierarchy and anti-de Sitter three dimensional gravity will be discussed as well as integrable features of relativistic particles and complex solitons having real conserved quantities.

On the Photon Vertex and Half-Integer Spin

Dahm, Rolf

Beratung für Informationssysteme und Systemintegration, Mainz, Germany

When rewriting the photon vertex of quantum electrodynamics in terms of geometrical quantities, various elements can be mapped directly to objects and properties known from classical projective geometry (PG). Elements of P^5 when mapped to line reps in P^3 exhibit their intrinsic Lorentz invariance associated to automorphisms of the Plücker-Klein quadric M_2^4, and the line reps when expressed by point or plane coordinates introduce (one-parameter) pencils, or formally gl(2,$\mathbb{R}$), or gl(1,$\mathbb{H}$) which covers su(2)$\oplus$u(1). This introduces binary forms and, using a potential approach of central forces, Schrödinger or Laplace equations and the respective special functions, as well as the projective generation of quadrics like in Dirac's approach which legitimates Clifford algebra elements as linear factors in invariant theory and the quadratic algebra to represent geometry. Physically, this identification allows for the original (classical) concept of moments in terms of tetrahedrons which on the one hand relates to previous work on SU(4) and SU$*$(4) in quantum representations. On the other hand, it relates to the classical physical definitions, however, exhibiting a factor 2 between contemporary (euclidean) moments and the tetrahedral construction used in the vertex. Finally, we discuss the equilibrium conditions with respect to gauge and Yang-Mills theories in general as well as the related objects and their transformation theory.

Pull back coherent states and Berezin type quantization.

Dey, Rukmini

Faculty of Mathematics, Bangalore, India

Berezin quantization is a method of defining a star product on the symbols of bounded linear operators on a Hilbert space where the star product satisfies the so called correspondence principle (i.e. under a formal limit of a defomation parameter the new theory reduces to a classical theory). In a seminal paper Berezin had defined this quantization for certain Kähler manifolds. We review certain aspects of this quantization, especially Berezin quantization of $\mathbb{C}P^n$. We mention some recent advances in which Berezin quantization is carried out on more general manifolds. Next, using embeddings of even dimensional compact manifolds into $\mathbb{C}P^n$ (after perhaps removing sets of measure zero), we define pullback coherent states and Berezin-type quantization of compact even dimensional manifolds. If time permits we will talk briefly about Berezin-Toeplitz quantization in this context. The last two works are jointly with K. Ghosh.

Canonical construction of invariant differential operators

Dobrev, Vladimir

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria

In this talk we make an overview of the program for canonical construction of invariant differential operators. Applying the procedure we start with the simplest example known to everybody and then show the latest more elaborate cases. We restrict to noncompact semisimple cases, though the procedure was applied to superalgebras, quantum groups, etc.

What hide from us the bipartite Hermite coherent states ?

Górska, Katarzyna

The Institute of Nuclear Physics, Kraków, Poland

I define and investigate properties of two classes of bipartite coherent states $|w_1, w_2\rangle_{1,\alpha}$ and $|w_1, w_2\rangle_{2,\alpha}$ built of the Hermite polynomials of complex variables and thus called bipartite Hermite coherent states. The states under study are labelled by complex numbers w_1, w_2 and indexed by a parameter α such that $\alpha \in (0, 1)$. Coherent states belonging to the first class involve products of holomorphic Hermite functions of a single complex variable and appear to be tensor products of single particle squeezed-coherent states while the states of the second class are formed using the non-factorizable holomorphic Hermite functions of two complex variables. They are not product states any longer. Physical model relevant to our construction is 2D harmonic oscillator for which the states $|w_1, w_2\rangle_{1,\alpha}$ and $|w_1, w_2\rangle_{2,\alpha}$ are not only squeezed-coherent but exhibit non-dynamical correlations. Model under study provides me with an example how different may be physical properties of various solutions to the same dynamical system.

Quantum time

Góźdź, Andrzej

Institute of Physics, Maria Curie-Skłodowska University, Lublin, Poland

Projection evolution idea (PEv) allows to introduce quantum time as a quantum observable represented either by an appropriate POV measure or as a time operator [Góźdź, A.; Góźdź, M.; Pędrak, A. Quantum Time and Quantum Evolution, Universe 2023, 9, 256]. This approach is flexible enough to construct time and space position observables in most reasonable quantum spacetime models. At the same time PEv formalism shows that the Pauli's arguments against existence of the time operator are here not applicable. To construct quantum spacetimes we are using quantization based on the Quantum Motion Algebras denoted here as QMA(G). These algebras are constructed from pairs of functions $(f, \check{\tau})$, where $f \in L^1(G)$ and $\check{\tau} \in l^1(G)$. Every irreducible representation of such algebra acting in the Hilbert space $\mathcal{K}$ obtained by the GNS procedure allows to construct resolution of unity $\int_G d\mu(g)\, |g><g|$ in $\mathcal{K}$ and the quantization $f \to \hat{f} = \int_G d\mu(g)\, |g> f(g) < g|$ which reproduces classical quantities as expectation values of the corresponding quantum observables, e.g., spacetime positions.

Decoherence limit of quantum systems obeying generalized uncertainty principle: new paradigm for Tsallis thermostatistics

Jizba, Petr

Faculty of Nuclear Sciences and Physical Engineering, CTU, Prague, Czech Republic

The generalized uncertainty principle (GUP) is a phenomenological model whose purpose is to account for a minimal length scale (e.g., Planck scale or characteristic inverse-mass scale in effective quantum description) in quantum systems. In my talk I will discuss possible observational effects of GUP systems in their decoherence domain. I first derive coherent states associated to GUP and unveil that in the momentum representation they coincide with Tsallis' probability amplitudes, whose non-extensivity parameter q monotonically increases with the GUP deformation parameter β. Secondly, for $\beta < 0$ (i.e., $q < 1$), I show that, due to Bekner–Babenko inequality, the GUP is fully equivalent to information-theoretic uncertainty relations based on Tsallis-entropy-power. Finally, I invoke the Maximal Entropy principle known from estimation theory to reveal connection between the quasi-classical (decoherence) limit of GUP-related quantum theory and non-extensive thermostatistics of Tsallis. This might provide an exciting paradigm in a range of fields from quantum theory to analog gravity. For instance, in some quantum gravity theories, such as conformal gravity, aforementioned quasi-classical regime has relevant observational consequences. I will discuss some of the implications.

The Nicolai-map approach to supersymmetry

Lechtenfeld, Olaf

Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

In 1980 Hermann Nicolai proposed a characterization of supersymmetric theories that became known as the Nicolai map. This is a particular nonlocal and nonlinear field transformation, whose perturbative expansion is given by fermion-line trees with bosonic leaves. Quantum correlation functions can by evaluated using the inversely transformed fields in the free theory. After initial promise and excitement (fuelling the author's PhD work!), the subject all but fell dormant for 35 years. Recently however, technical progress in the construction as well as a deeper insight into the nature of the map have been achieved, from quantum mechanics to super Yang–Mills in various dimensions. I will present the Nicolai map from this modern perspective and touch on some of the current developments.

Representations of the orthosymplectic Yangian

Molev, Alexander

School of Mathematics and Statistics, University of Sydney, NSW 2006, Australia

The Yangians form a remarkable family of quantum groups with a deep and substantive representation theory and numerous connections in mathematical physics. According to the original definition of Drinfeld, the Yangian $\mathrm{Y}(\mathfrak{a})$ associated with a simple Lie algebra $\mathfrak{a}$ is a canonical deformation of the universal enveloping algebra $\mathrm{U}(\mathfrak{a}[u])$ in the class of Hopf algebras. The Yangians admit at least three different presentations, including the R-matrix presentation going back to the work of Faddeev's school in the 1980s. It is the R-matrix approach which turned out to be more suitable for the introduction of the super-versions of the Yangians as given by Nazarov (for the general linear Lie superalgebras, 1991) and Arnaudon *et al.* (for the orthosymplectic Lie superalgebras, 2003). More recently, Drinfeld-type presentations of the super Yangians were produced by a universal approach based on the Gauss decomposition of the generator matrices. The classification problem for simple finite-dimensional modules over the Yangians associated with the orthosymplectic Lie superalgebras $\mathfrak{osp}_{1|2n}$ and $\mathfrak{osp}_{2|2n}$ has been solved recently (2022). We will discuss the solution which describes the representations in terms of their highest weights depending on tuples of monic polynomials in one variable. Key arguments rely on an explicit construction of a family of elementary modules of the Yangian for $\mathfrak{osp}_{1|2}$. A wide class of irreducible representations of this Yangian can be produced by taking tensor products of the elementary modules.

Algebraic Bethe Ansatz for models based on orthogonal algebras

Ragoucy, Eric

LAPTh-CNRS, Annecy, France

We consider integrable models with o_{2n+1} symmetry. Within the framework of Algebraic Bethe Ansatz, we construct their Bethe vectors and compute their scalar products. The calculation is done using also the current presentation of Yangians.

Tensor eigenvalue distributions through field theoretical methods

Sasakura, Naoki

ukawa Institute for Theoretical Physics, Kyoto University, Kyoto, Japan

Tensor models provide an interesting direction in pursuit of quantum gravity. Understanding their dynamics would be an important part of the pursuit, which could be partly captured by distributions of tensor eigenvalues in tensor models, such as Wigner's semi-circle law in matrix models. We show how the distributions can be computed by field theoretical tools, and discuss several possible extensions of the procedure.

Boson Stars and Electrostatic Hairy Black Holes

Shnir, Yakov

Institute of Physics, Carl von Ossietzky University of Oldenburg, Oldenburg, Germany

We study charged spherically symmetric boson stars and hairy black holes in the two-component scalar Einstein-Maxwell-Friedberg-Lee-Sirlin model with a symmetry breaking potential. The asymptotically flat black holes carry resonant scalar Q-hair. As expected, these hairy black holes give rise to non-uniqueness. When comparing these solutions with the corresponding charged boson stars and Reissner-Nordström black holes, we find a different pattern in the case of a massive real scalar component and a massless one. We demonstrate that, as the real component becomes massless, the resonant hairy black holes bifurcate from Reissner-Nordström black holes for sufficiently small gravitational coupling.

Partition functions of paraboson and parafermion systems

Van der Jeugt, Joris

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria

Parabosons and parafermions, algebraically characterized by triple relations rather than just (anti)-commutation relations, have been around for more than 60 years. Over the recent years, new mathematical results have been obtained for their representations, in particular character formulae. In the present talk, we give a short review of the algebraic structures behind parabosons and parafermions, and of their representations. We show how the new expressions for characters lead to proper forms of grand partition functions for systems of parabosons and parafermions. These forms of the partition function allow the computation of statistical and thermodynamic functions for such systems. We discuss some examples, such as the average number of particles on an orbital, and the average number of particles in the system.

ABSTRACTS OF PARTICIPANTS

New class of solutions in the non-minimal O(3)-sigma model

Almeida, Carlos Alberto

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For the study of topological vortices with non-minimal coupling, we built a kind of non-canonical O(3)-sigma model, with a Maxwell term modified by a dielectric function. Through the BPS formalism an investigation is made on possible configurations of vortices in topological sectors of the sigma model and the real scalar field. For a particular ansatz, the solutions of the topological sector of the real scalar field are described by the known kink solutions. On the other hand, when studying the vortices in non-minimal sector of the pure O(3)-sigma model, it is detected the emergence of solutions that generate solitary waves similar to structures derived from a KdV-like theory. We observed that in the study of mixed models, namely, the topological sector of the O(3)-sigma model coupled to the topological sector of the real scalar field, the vortex solutions assume a profile of a step function. Then, when kinks of the topological sector of the scalar field are interacting with the field of the sigma model, it makes the field solutions of the O(3)-sigma model become extremely localized, making the vortice structures non-physical.

Magnetization Properties, Superstable Points, and Cycles of Antiferromagnetic Spin-1 Diamond Chains with Nodal-nodal Interactions

Amatuni, Gayane

CANDLE SRI, Yerevan, Armenia

The main subject considered in this paper is the appearance of super-stable points and super-stable cycles from the point of view of antiferromagnetic spin-1 Ising and Ising-Heisenberg models on diamond chains with nodal-nodal interactions. We also studied their connection with magnetization plateaus. Using the recurrence relations technique we obtain the multidimensional rational mappings, which describe the statistical properties of the models. The stability properties of the multidimensional mapping make it obvious that the magnetization plateau is related to the dynamic properties. We study those stability properties - the magnetization plateau as the behavior of the maximum Lyapunov exponent. The super-stable points and cycles for spin-1 models on diamond chains have been tested for a number of parameters.

Magnetic Properties and Entanglement of the Octanuclear Nickel Phosphonate-based Cage

Ananikian, Nerses

FNSPE CTU, Prague, Czech Republic

The primary objective of a paper is a study of quantum magnetic properties and entanglement of an octanuclear nickel phosphonate-based cage. For this cage it was experimentally measured the magnetic susceptibility as a function of temperature. The measurements indicate the coexistence of both antiferromagnetic and ferromagnetic interactions between the magnetic centers, Ni ions with spin 1. We theoretically study the magnetic properties of such compounds. The magnetic susceptibilities near the magnetization jumps have peaks depending on the external magnetic field at low temperatures. We calculate these peaks at low temperatures theoretically and are suggesting to compare them with experimental measurements in future.Thermal entanglement (negativity) and logarithmic negativity are also calculated. The peak positions of the magnetic susceptibilities coincide with the magnetic jumps observed in the thermal entanglement (negativity) and logarithmic negativity.

Dynamical consistency conditions for rapid turn inflation

Anguelova, Lilia

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We derive consistency conditions for sustained slow roll and rapid turn inflation in two-field cosmological models with oriented scalar field space, which imply that inflationary models with field-space trajectories of this type are non-generic. In particular, we show that third order adiabatic slow roll, together with large and slowly varying turn rate, requires the scalar potential of the model to satisfy a certain nonlinear second order PDE, whose coefficients depend on the scalar field metric. We also derive consistency conditions for slow roll inflationary solutions in the so called “rapid turn attractor” approximation, as well as study the consistency conditions for circular rapid turn trajectories with slow roll in two-field models with rotationally invariant field space metric. Finally, we argue that the rapid turn regime tends to have a natural exit after a limited number of e-folds.

States, observables and symmetries in p-adic quantum mechanics

Aniello, Paolo

Università di Napoli “Federico II”, Napoli, Italy

In the framework of quantum mechanics constructed over a quadratic extension of the field of p-adic numbers, we provide an algebraic definition of physical states. The corresponding observables are then defined as SOVMs, the p-adic counterpart of the POVMs associated with a quantum system over the field of complex numbers. Differently from the standard complex setting, the space of states of a p-adic quantum system possesses a natural *affine* — rather than convex — structure. Hence, symmetry transformations may be defined, in a natural way, as suitable maps that preserve this affine structure.

Revisiting Atiyah-Hitchin manifold in the generalized Legendre transform

Arai, Masato

Faculty of Science, Yamagata University, Yamagata, Japan

We revisit construction of the Atiyah-Hitchin manifold in the generalized Legendre transform approach. This is originally studied by Ivanov and Rocek and is subsequently investigated more by Ionas, in the latter of which the explicit forms of the Kähler potential and the Kähler metric are calculated. There is a difference between the former and the latter. In the generalized Legendre transform approach, a Kähler potential is constructed from the contour integration of one function with holomorphic coordinates. The choice of the contour in the latter is different from the former's one, whose difference may yield a discrepancy in the Kähler potential and eventually in the Kähler metric. We show that the former only gives the real Kähler potential, which is consistent with its definition, while the latter yields the complex one. We derive the Kähler potential and the metric for the Atiyah-Hitchin manifold in terms of holomorphic coordinates for the contour considered by Ivanov and Roček.

Semiclassical asymptotics and entropy

Barron, Tatyana

Department of Mathematics, University of Western Ontario, Canada

Joint work with: M. Saikia

We study the entanglement of quantum states that are associated with submanifolds of Kähler manifolds. We discuss the semiclassical asymptotics (as $\hbar \to 0$) of the entanglement entropy, or more generally, entanglement of formation. We use geometric quantization of $\mathbb{CP}^1$ to provide an explicit example.

Noncommutative geodesics and quantum mechanics

Beggs, Edwin

Department of Mathematics, Computational Foundry, Swansea University, Swansea, UK

Joint work with: Majid, Shahn

We consider velocity fields and parallel transport in noncommutative geometry. This gives a flow of states on an algebra by the KSGNS construction for completely positive maps on C^* algebras and connections on Hilbert C^*-bimodules. Maintaining the normalisation of the states leads to real noncommutative vector fields and their divergences. This can be applied to the noncommutative Heisenberg algebra, and parallel transport for a suitable connection gives

1) The usual Schrodinger equation (with potential), and

2) The Klein-Gordon equation (with EM fields), with parameter the proper time. Just as GR gives test particles having geodesic motion, in these cases quantum mechanics can be considered as geodesic motion on a noncommutative algebra. I will end with some comments on calculi on Heisenberg algebras on curved spaces.

Rogue wave solutions for the integrable generalized spin model

Bekova, Guldana

Department of Physics and Technical Disciplines, Kh.Dosmukhamedov Atyrau University, Atyrau, 060000, Kazakhstan

In this paper, one of the generalized Heisenberg models for ferromagnets is studied - the Myrzakulov-LXXIII (M-LXXIII) equation. It has already been proved that the M-LXXIII equation is Lakshmanan (geometric) and gauge equivalent of the complex equation for short pulses. Using the Lax pair, the Darboux transform (DT) of this equation is constructed. A determinant representation of the single, double, and n-fold equations M-LXXIII is also obtained. As examples of the application of transformations, one- and two-soliton solutions are obtained from trivial solutions. Graphs were constructed based on the solutions and their dynamics were studied.

Shapes of magnetic monopoles in $SU(2)$ models

Beneš, Petr

Institute of Experimental and Applied Physics, Czech Technical University in Prague, Prague, Czech Republic

Joint work with: Blaschke, Filip

We present a systematic exploration of a general family of effective $SU(2)$ models with an adjoint scalar. We discuss a redundancy in this class of models and use it to identify seemingly different, yet physically equivalent models. We construct the Bogomol'nyi–Prasad–Sommerfield (BPS) limit and derive analytic monopole solutions. In contrast to the 't Hooft–Polyakov monopole, included here as a special case, these solutions tend to exhibit more complex energy density profiles. Typically, we obtain monopoles with a hollow cavity at their core where virtually no energy is concentrated; instead, most of the monopole's energy is stored in a spherical shell around its core. Moreover, the shell itself can be structured, with several "sub-shells".

Representations of the rank-2 Racah algebra

Bertrand, Sebastien

Department of Mathematics, University of Hawaiʻi at Mānoa, Honolulu, USA

Joint work with: Post, Sarah

The Racah algebra is a very rich algebra appearing in more than one field of mathematical physics: Superintegrable Hamiltonian systems on the hypersphere, multivariate Racah Polynomials, and su(1,1) recoupling problem. In this presentation, we will use the latter to construct the algebras of rank 0, 1, and 2. For the (trivial) rank-0 case, it leads to the well-known Clebsch-Gordan coefficients. The representation of the rank-1 case is known, but very little is known about higher-rank cases. We will then explore many properties of the Racah algebra and discuss rank-2 representations. (This is a joint work with Prof. Sarah Post.)

Topology of critical points in black hole thermodynamics

Bhamidipati, Chandrasekhar

School of Basic Sciences, Indian Institute of Technology Bhubaneswar, Bhubaneswar, India

Joint work with: Pavan Kumar Yerra, Sudipta Mukherji

Black holes in anti de Sitter spacetimes undergo phase transitions which typically lead to the existence of critical points. Following recent proposals on using Duan's ϕ-mapping theory to study phase transition points, we present a topological classification of critical points of black holes in Einstein gravity, as well as in Gauss-Bonnet and Born-Infeld theories. We find that Gauss-Bonnet terms do not change the topological class of critical points in charged black holes in AdS, unlike the Born-Infeld corrections. We also compute the topological charge of the Hawking-Page transition point for black holes in AdS, using Bragg-Williams construction of an off-shell free energy. The computation is further generalised to study the equilibrium phases of these systems, which follow from the saddle points of the free energy. A holographic understanding of the results is presented.

Reduction of L_∞-algebras of observables on multisymplectic manifolds

Blacker, Casey

Department of Mathematical Sciences, George Mason University, Fairfax, USA

We present a method for obtaining a reduced L_∞-algebra of observables on a premultisymplectic manifold (M, ω) in the presence of a compatible Lie group action and moment map. Under sufficiently strong conditions, this construction reproduces the Dirac, Śniatycki–Weinstein, and Arms–Cushman–Gotay reduced Poisson algebras in the symplectic setting. After first reviewing geometric and algebraic reduction of symplectic Hamiltonian manifolds, we indicate how these results extend to the multisymplectic paradigm, and then describe the canonical embedding of the algebraic reduction of a multisymplectic Hamiltonian system into the L_∞-algebra of observables on the geometric reduced space. This talk is based on joint work with Antonio Miti and Leonid Ryvkin.

Noncommutative Fibrations

Blake, James

Computational Foundry, Bay Campus, Swansea University, Swansea, Wales, United Kingdom

We construct a Leray-Serre spectral sequence for fibrations for de Rham cohomology on noncommutative algebras. The fibrations are bimodules with zero-curvature extendable bimodule connections satisfying an additional condition. By the KSGNS construction, completely positive maps between C*-algebras correspond to Hilbert C*-bimodules. We give examples of fibrations on group algebras and matrix algebras. Lastly, we look at an idea of how we might define noncommutative cofibrations. This research has been a joint work with my PhD supervisor Edwin Beggs.

Mechanization of scalar field theory in (1+1)-dimensions

Blaschke, Filip

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Joint work with: O. N. Karpíšek, L. Rafaj

The dynamic of a continuous field exemplified in the scattering of kinks in (1+1)-dimensions exhibits intricate chaotic behaviour, fractals in the pattern of bouncing windows, and much more. However, most of this complexity can be boiled down to just a few effective degrees of freedom. There is currently no canonical way of finding them and the construction of effective models is currently somewhat of an art form. We present the first systematic way of building effective 'mechanical' theories that are qualitatively faithful to the original field theory. Being agnostic and simple, mechanization can be used as a tool for systematic exploration. Through simple examples, we show how one can rediscover many of the hallmarks of soliton physics via this procedure.

Generation of non-Hermitian Hamiltonian through non-linear equations

Blazquez, Maria

Instituto Politécnico Nacional, Miguel Othón de Mendizábal S/N, Ciudad de México, México

Joint work with: S. Cruz y Cruz

In this work it is considered the generation of different families of non-Hermitian Hamiltonians with real spectra by means of the factorization method. The construction of complex potentials exhibiting linear and quadratic spectra in terms of the quantum number is examined. The solution of the corresponding spectral problem is given in terms of the intertwining equations in each case. The orthogonality and the resolution to the identity are stated in the biorthogonal approach. Finally, the algebraic properties of the factorization operators are used to determine the spectrum generating algebra of each system.

Dynamical fixed points in holography: theory and cosmological applications

Buchel, Alex

Department of Physics and Astronomy, University of Western Ontario, Ontario, Canada

Dynamical fixed points are late-time attractors of interactive QFTs that differ from thermal equilibria by a constant entropy production rate. We use holographic framework to analyze such fixed points of strongly coupled gauge theories, driven by homogeneous and isotropic expansion of the background metric - equivalently, a late-time dynamics of a corresponding QFT in Friedmann-Lemaitre-Robertson-Walker Universe. As an application, we discuss gravitational reheating of quark-gluon plasma in the exit from the early-cosmology inflation.

Quantum Metropolis Solver

Campos Ortiz. Roberto

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Joint work with: M. Casares, Pablo A., Martin-Delgado

The efficient resolution of optimization problems is one of the key issues in today's industry. This task relies mainly on classical algorithms that present scalability problems and processing limitations. Quantum computing has emerged to challenge these types of problems. In this paper, we focus on the Metropolis-Hastings quantum algorithm that is based on quantum walks. We use this algorithm to build a quantum software tool called Quantum Metropolis Solver (QMS). We validate QMS with the N-Queen problem to show a potential quantum advantage in an example that can be easily extrapolated to an Artificial Intelligence domain. We carry out different simulations to validate the performance of QMS and its configuration.

Second order Lagrangians for (2+1)-dimensional generalized Boussinesq equations and an extension of the Krupka-Betounes equivalent

Palese, Marcella

Department of Mathematics, University of Torino, Italy

Joint work with: Zanello, F.

We determine second order Lagrangians for (2 + 1)-dimensional generalized Boussinesq equations and we discuss some aspects concerning conservation laws associated with invariance properties of their extended 'full' equivalents, in particular of Krupka-Betounes type. Such equivalents are constructed by means of a recursive formula involving geometric integration by parts formulae.

Exact solution of the $D_2^{(2)}$ model with generic open boundary fields

Cao, Junpeng

Institute of Physics, Chinese Academy of Sciences, Beijing, China

Exact solution of the quantum integrable $D_2^{(2)}$ spin chain with generic integrable boundary fields is constructed. It is found that the transfer matrix of this model can be factorized as the product of those of two open staggered anisotropic XXZ spin chains. Based on this identity, the eigenvalues and Bethe ansatz equations of the $D_2^{(2)}$ model are derived via off-diagonal Bethe ansatz.

On the Asymmetric Harmonic Oscillator

Chadzitaskos, Goce

FNSPE CTU, Prague, Czech Republic

We have constructed formal coherent states for an asymmetric harmonic oscillator, where the asymmetry parameter is the ratio of spring constants. The work deals with the study of their properties. These states generally do not satisfy all the required properties for coherent states. During the time development, coherent states introduced in this way become decoherent. For specific asymmetry parameters, coherent states can be constructed on the subspace of states that preserve coherence during time evolution.

On-Shell action of type IIB theory on $AdS_5 \times S^5$

Chakrabarti, Subhroneel

Institute of Physics of the Czech Academy of Sciences & CEICO, Prague, Czech Republic

In this talk, I will revisit the problem of computing the on-shell action for type IIB Supergravity on $AdS_5 \times S^5$. The value of this on-shell action is expected to be non-zero and is entirely fixed by the dual CFT, contrary to the textbook supergravity prescription. I will use Sen's formalism for type IIB supergravity, which incorporates the self-dual five-form field strength in a manifestly covariant way. I will show that this formalism naturally leads to a boundary term that resolves the discrepancy with AdS/CFT and also provides a strong candidate for the boundary term of the full type IIB superstring action. This has important implications for the validity of the AdS/CFT correspondence in $AdS_5 \times S^5$ at the string level and for the understanding of boundary terms in string theory in general.

Parity-Time Symmetric Solitons in the Complex KP Equation

Chang, Jen-Hsu

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One constructs the parity-time symmetric solitons in the complex KP Equation using the totally non-negative Grassmannian. We obtain that every element in the totally non-negative orthogonal Grassmannian corresponds to a parity-time symmetric solitons solution.

Categorified Quantum Groups, Braided Monoidal 2-Categories and the Spin-Kitaev Model

Chen, Hank

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It is well-known since the work of Hopf, Drinfel'd, Majid and Witten in the late 20th century that Hopf algebra quantum groups play a signification role in both physics and mathematics, in particular topology and geometry. In particular, the category of representations of quantum groups are braided, and hence captures invariants of knots. This talk is based on works with F. Girelli, where we develop a systematic categorification of the theory of quantum groups/bialgebras, including monoidal weakenings, and prove that their 2-representations form a braided monoidal 2-category as defined in Gurski and Kong. We will then apply our general framework to unite the following two descriptions of the 4D toric code and its spin variant: the 2-categorical approach by Johnson-Freyd vs. the 2-group field theoretic approach by Zhu et al.

The Shigesada–Kawasaki–Teramoto model: conditional symmetries, exact solutions and their properties

Cherniha, Roman

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Joint work with: V. Davydovych, J.R. King

We study a simplification of the well-known Shigesada–Kawasaki–Teramoto model, which consists of two nonlinear reaction-diffusion equations with cross-diffusion. A complete set of Q-conditional (nonclassical) symmetries is derived using an algorithm adopted for the construction of conditional symmetries of nonlinear systems with cross-diffusion. The symmetries obtained are applied for finding a wide range of exact solutions, possible biological interpretation of some of which being presented. Moreover, an alternative application of the simplified model related to the polymerisation process is suggested and exact solutions are found in this case as well.

Negative radiation pressure in Bose–Einstein condensates

Ciurla, Dominik

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Two-component Bose–Einstein condensates can be described in the mean-field approximation, using the coupled nonlinear Schrödinger equations. The interactions of plane waves with solitons in the quasi-1D version of this model are studied. In the talk, the results for dark and dark-bright solitons are presented, comparing numerical simulations with an effective linearized approach. In some of the considered setups, the force acting on the soliton has an opposite direction to the incoming wave. This unusual effect is called the negative radiation pressure (NRP) and has been discovered previously in other systems. Hopefully, this research can be experimentally verified, making NRP no longer a purely theoretical concept, but a real phenomenon observed in nature.

Graphical calculus for quantum vertex operators

De Clercq, Hadewijch

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Graphical calculus provides a diagrammatic framework for performing topological computations with morphisms in strict ribbon categories. This amounts to a functorial identification of such morphisms with oriented diagrams colored by a ribbon category, such as the category of finite-dimensional representations of a quantum group. In this talk I will explain how the well-known Reshetikhin-Turaev graphical calculus can be extended to a larger category of quantum group representations, encompassing the q-analogue of the BGG category $\mathcal{O}$. In particular, this extended framework allows to graphically represent quantum vertex operators on Verma modules, as well as morphisms depending on a dynamical parameter, such as dynamical R-matrices. I will demonstrate the potential of this approach by graphically deriving q-difference equations for twisted trace functions of N-point quantum vertex operators. These include the dual q-KZB and dual Macdonald-Ruijsenaars equations first obtained by Etingof and Varchenko, as well as some generalisations. This talk is based on joint work with Nicolai Reshetikhin (UC Berkeley) and Jasper Stokman (University of Amsterdam).

Generalized integrals of Macdonald and Gegenbauer functions

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Joint work with: Błażej Ruba and Christian Gaß

We compute bilinear integrals of Macdonald and Gegenbauer functions. These integrals are convergent only for a limited range of parameters. However, when one uses *generalized integrals* they can be computed essentially without restricting the parameters. The generalized integral is a linear functional extending the standard integral to a certain class of functions involving finitely many homogeneous non-integrable terms at the edpoints of the interval. For generic values of parameters, generalized bilinear integrals of Macdonald and Gegenbauer functions can be obtained by analytic continuation from the region in which the integrals are convergent. In the case of integer parameters the generalized integrals are *anomalous*, in particular, they are not scaling invariant. Bilinear integrals appear naturally when we consider Green's functions of the Laplacian with *point potentials*. Those involving Macdonald functions are relevant for Euclidean spaces. Those involving Gegenbauer functions are relevant for the *spheres* and *hyperbolic spaces*. Usual integrals suffice in dimensions 1,2,3, and then point potentials lead to self-adjoint realizations of the Laplacian. In higher dimensions we need to use generalized integrals and the corresponding Green's functions are not associated with bounded operators.

Exact analytical solutions for 2D Dirac materials interacting with external fields

Díaz-Bautista, Erik

Área Académica de Matemáticas y Física, Universidad Autónoma del Estado de Hidalgo, Hidalgo, México

Joint work with: M-Z. Julio A, O-C. Daniel

We address the model of two-dimensional Dirac materials interacting with external electric and magnetic fields with translational symmetry in order to obtain exact solutions for the problem. To solve the eigenvalue equation that arises from the effective Hamiltonian of these materials, we present an algorithm that allows us to decouple the differential equations that are obtained for the spinor components.

Integrability properties of the Hermite–Padé approximation and interpolation problems

Doliwa, Adam

Faculty of Mathematics and Computer Science, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland

We show that solution to the Hermite–Padé type I approximation problem leads in a natural way to a subclass of solutions of the Hirota (discrete Kadomtsev–Petviashvili) system and of its adjoint linear problem. We study the place of the reduced system within the integrability theory, which results in finding multidimensional (in the sense of number of variables) extension of the discrete-time Toda chain equations. The study can be generalized in two directions. The first one is the interpolation analogue of the Hermite–Padé problem for which we provide determinant solution and we write down the corresponding non-autonomous multidimensional discrete-time Toda equations. Then we introduce and solve the non-commutative version of the approximation problem. Its solution, expressed by quasideterminants, gives a subclass of solutions of the non-commutative Hirota system and of its linear problem. We also prove integrability of the constrained system, which in the simplest 2D case is the non-commutative discrete-time Toda lattice equation known from the theory of non-commutative Padé approximants and matrix orthogonal polynomials.

Deformation quantization approach to quantizing a rigid body in an external electromagnetic field

Domański, Ziemowit

Institute of Mathematics, Poznań University of Technology, Poznań, Poland

First we present a complete theory of a non-formal deformation quantization on the cotangent bundle of a Lie group. The developed theory is a version of the strict deformation quantization introduced by M. A. Rieffel. The electromagnetic field is incorporated into the theory by modifying the symplectic structure of the phase space. Next we use the developed theory to quantize a rigid body. Two non-equivalent quantizations are received resulting in an integer and half-integer angular momentum. The spectrum of the Hamilton operator is calculated in the case of the rigid body in a magnetic field of a magnetic monopole.

Two-body Coulomb problem and $g^{(2)}$ algebra

Escobar Ruiz, Adrian

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Joint work with: Alexander V. Turbiner

Taking the Hydrogen atom as an example it is shown that if the symmetry of a three-dimensional system is $O(2) \oplus Z_2$, the variables (r, ρ, φ) allow a separation of the variable φ, and the eigenfunctions define a new family of orthogonal polynomials in two variables, (r, ρ^2). These polynomials are related to the finite-dimensional representations of the algebra $gl(2) \ltimes R^3 \in g^{(2)}$ (discovered by S. Lie around 1880), which occurs as the hidden algebra of the G_2 rational integrable system of 3 bodies on the line (the Wolfes model). Namely, those polynomials occur intrinsically in the study of the Zeeman effect on Hydrogen atom.

Generalized stochastic Lie–Hamiltonian systems: Exact solutions and superposition rules for SIS epidemic models

Fernández-Saiz, Eduardo

Joint work with: Rutwig Campoamor-Stursberg, Francisco J. Herranz

An expanded version of a previously proposed stochastic SIS epidemic model with a variable infection rate is taken into consideration using formal generalized stochastic Hamiltonian systems based on the theory of Lie-Hamilton systems. It is demonstrated that these systems typically admit an exact solution, regardless of the specific interpretation of the time-dependent coefficients, with the exception of the greatest extension within the classification of Lie-Hamilton systems, for which a superposition rule is developed. Any SIS epidemic model that maintains the aforementioned properties is submitted to the method's algebraic framework. we obtain exact solutions for generalized SIS Hamitonian models based on the book and oscillator algebras, denoted respectively by $\mathfrak{b}_2$ and $\mathfrak{h}_4$. The last generalization corresponds to a SIS system possessing the so-called two-photon algebra symmetry $\mathfrak{h}_6$, according to the embedding chain $\mathfrak{b}_2 \subset \mathfrak{h}_4 \subset \mathfrak{h}_6$, for which an exact solution cannot generally be found, but a superposition rule is explicitly given.

Fermions in Doubly Special Relativity: a mixed geometric and algebraic approach

Franchino-Viñas, Sebastian

Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Fermions, being one of the pillars of the standard model, should necessarily be introduced in any proposal for quantum gravity. In this talk, we will show how a Dirac equation can be naturally defined in doubly special relativity, employing the notion of curved momentum space. Based on https://doi.org/10.1088/1361-6382/acb4d4 (arXiv:2203.12286).

Dirac materials in parallel electromagnetic fields generated by supersymmetry

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Joint work with: J.C. Perez-Pedraza, A. Raya

By means of Supersymmetric Quantum Mechanics (SUSY-QM) [?], the Dirac equation describing a Dirac material [?] in parallel electromagnetic fields is solved. Considering static but non-uniform electromagnetic profiles and transnational invariance in y-direction, the Dirac equation is transformed into two decoupled pairs of equations corresponding to each chirality. Taking a trigonometric vector potential as well as a hyperbolic scalar potential, we arrive at SUSY partner Pöschl-Teller-like potentials. Looking for their conditions to support a zero-mode, we obtain a nontrivial current density in the same plane of the electromagnetic fields but perpendicular to both, suggesting the possibility of realizing the planar Hall effect [?]. Furthermore, this current density, due to the chiral symmetry is conserved, turns out to be the addition of the chiral right- and left-current densities.

Coherent states and beyond in Quantum Mechanics, Quantum Optics and Signal Analysis, A review

Gazeau, Jean-Pierre

Université Paris Cité, CNRS, Astroparticule et Cosmologie, Paris, France

Various generalisations (group theoretical, nonlinear, discrete, ...) of Glauber-Sudarshan coherent states will be presented in a unified way, with their statistical properties and their role in Quantum Mechanics, Quantum Optics, Signal Analysis, and quantization with or without Planck constant.

Title Negative flows of generalized KdV and mKdV hierarchies and their gauge-Miura transformations

Gomes, Jose

Instituto de Fisíca Teórica, IFT-Unesp, São Paulo, Brasil

Joint work with: Y. F. Adans, G. Starvaggi França, G. V. Lobo and A. H. Zimerman

We show that Miura transformation can be extended to a gauge transformation that implies several new types of relation among the negative flows of the KdV and mKdV hierarchies. Contrary to the positive flows, such a “gauge-Miura” correspondence becomes degenerate, namely more than one negative mKdV-type model are mapped into a single negative KdV-type model. For instance, the sinh-Gordon model and another negative mKdV flow are mapped into a single negative KdV flow, which then inherits solutions of both former models. The gauge-Miura correspondence implies a rich degeneracy regarding solutions of these hierarchies. Similar results for generalized versions of the KdV and mKdV hiearchies associated to affine Lie algebra sl (r + 1) are considered.

Geometry of bounded critical phenomena

Gori, Giacomo

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Joint work with: A. Trombettoni, A. Galvani

What would you do if you were a system at criticality confined in a bounded domain? Of course you would forget about details of the interaction, and lattice spacing, flowing to an RG fixed point. Besides attaining this bulk universal behavior you would also try (boundary condition permitting) to forget about the confinement becoming ”as uniform as possible”. Implementing this requirement in absolute geometric language, the one used by general relativity, we obtain novel predictions for the structure of one- and two-point correlators. These predictions are tested successfully against numerical experiments for the most relevant 3d critical models (Ising, XY, percolation).

Cayley-Dickson sedenions, triality, and three generations of fermions

Gresnigt, Niels

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An algebraic representation of three generations of fermions with unbroken $SU(3)_C \times U(1)_{em}$ symmetry based on the Cayley-Dickson algebra of sedenions $\mathbb{S}$ is constructed. Recent attempts to clarify the geometric and algebraic roots of the Standard Model based on the four normed division algebra over the reals provide a compelling and unified description of both particle multiplets and gauge symmetries, although typically only for

a single generation. Despite numerous attempts, an algebraic origin for the existence of exactly three generations has proven difficult to substantiate. We propose that the Cayley-Dickson algebra of sedenions $\mathbb{S}$ may provide a suitable algebraic structure to represent three generations. We initially represent one generation of leptons and quarks in terms of a subset of all left actions of the complex sedenions on themselves. Subsequently we employ the finite group S_3, which are automorphisms of $\mathbb{S}$ but not of $\mathbb{O}$ to generate two additional generations.

Symmetry and reduction for a class of degenerate second order Lagrangians

Gümral, Hasan

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For a class of degenerate second order Lagrangians, Hamiltonian structures are obtained via Ostrogradskii method and Dirac-Bergman algorithm. A comparative discussion, based on degeneracy, degree of freedom and dimension of symmetry group, of possible reduction procedures, a la Routh, Poincaré and Marsden-Weinstein, by symmetries of configuration spaces, of both Lagrangian and Hamiltonian formalisms is presented. It is shown that reduction of the chiral oscillator with $SE(2)$ symmetry requires an extension to oscillator algebra.

The Boolean quadratic forms and tangent law

Hecka, Patrycja

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Ejsmont and Lehner (*The free tangent law*, 2020) study the limit sums of free commutators and anticommutators and show that the generalized tangent function

$$\frac{\tan z}{1 - x \tan z}$$

describes the limit distribution. This is the generating function of the higher order tangent numbers of Carlitz and Scoville (*Tangent numbers and operators*, 1972) which arose in connection with the enumeration of certain permutations. I will talk about the limit of weighted sums of Boolean commutators and anticommutators and I will show that the shifted generalized tangent function appears in a limit theorem. In order to do this, I shall provide an arbitrary cumulants formula of the quadratic form. I will also apply this result to show several theorems in a Boolean probability theory.

The (extended) noncommutative spaces of geodesics with κ-Poincaré, Galilei and Carroll symmetries

Herranz, Francisco J.

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Joint work with: Angel Ballesteros, Giulia Gubitosi and Ivan Gutierrez-Sagredo

The noncommutative spacetimes associated to the κ-Poincaré relativistic symmetries and their "non-relativistic" (Galilei) and "ultra-relativistic" (Carroll) limits are indistinguishable, since their coordinates satisfy the same algebra. We show that the three quantum kinematical models can be differentiated when looking at the associated spaces of time-like worldlines. Specifically, we present the noncommutative spaces of time-like geodesics with κ-Galilei and κ-Carroll symmetries as contractions of the corresponding κ-Poincaré space and we show that these three spaces are defined by different algebras. In particular, the κ-Galilei space of worldlines resembles the so-called Euclidean Snyder model, while the κ-Carroll space turns out to be commutative. Furthermore, we identify the map between quantum spaces of geodesics and the corresponding noncommutative spacetimes, which requires to *extend* the space of geodesics by adding the noncommutative time coordinate.

On the solutions of universal differential equation by noncommutative Picard-Vessiot theory

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Joint work with: V. C. Bui, Q. H. Ngô

Basing on Picard-Vessiot theory of noncommutative differential equations and algebraic combinatorics on noncommutative formal series with holomorphic coefficients, various recursive constructions of sequences of grouplike series converging to solutions of universal differential equation are proposed. Basing on monoidal factorizations, these constructions intensively use diagonal series and various pairs of bases in duality, in concatenation-shuffle bialgebra and in a Loday's generalized bialgebra. As applications, the unique solution, satisfying asymptotic conditions, of Knizhnik-Zamolodchikov equations is provided by *dévissage*.

Electron in triangular graphene dots

Hrivnák, Jiří

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Joint work with: L. Motlochová

Two types of honeycomb lattice Fourier–Weyl transforms associated to the irreducible crystallographic root system A_2 are utilized to study electronic properties of triangular graphene quantum dots. The triangular dots with armchair and zigzag edges are represented by two fundamentally different geometric configurations of the honeycomb lattice inside the fundamental domain of the A_2 affine Weyl group. The Schrödinger equations produced by tight-binding models of electron propagation with the nearest and next-to-nearest couplings are exactly solved through armchair and zigzag honeycomb Fourier–Weyl transforms. The inclusion of boundary conditions in the tight-binding Hamiltonians provides four types of electronic stationary states expressed via the honeycomb Weyl orbit functions. The contrasting behavior of the armchair and zigzag electronic probability densities is demonstrated.

Dimensional reduction approach to superintegrable $\mathcal{PT}$-symmetric systems

Inzunza, Luis

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An extension of the Marsden—Weinsten reduction is applied to the geodesic motion in a complex homogeneous space for obtaining superintegrable $\mathcal{PT}$-invariant systems on the n-dimensional sphere. The main objects in this technique are the complexified maximal Abelian subalgebras of the special unitary group. The transformations associated with them allow us to distinguish the "ignorable" coordinates that the reduction procedure eliminates. Additionally, the integrals of the generated systems are the reduced element on the invariant subspace in the corresponding enveloping algebra. Examples at one and two dimensions are described at the quantum level, providing new systems with real spectra or $\mathcal{PT}$-symmetry breaking.

The Grad–Shafranov Equation in Cap-Cyclide Coordinates: The Heun Function Solution

Ishkhanyan, Artur

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Joint work with: Flavio Crisanti

The Grad–Shafranov plasma equilibrium equation was originally solved analytically in toroidal geometry, which fitted the geometric shape of the first Tokamaks. The poloidal surface of the Tokamak has evolved over the years from a circular to a D-shape. The natural geometry that describes such a shape is the prolate elliptical one, i.e., the cap-cyclide coordinate system. When written in this geometry, the Grad–Shafranov equation can be solved in terms of the general Heun function. In this paper, we obtain the complete analytical solution of the Grad–Shafranov equation in terms of the general Heun functions and compare the result with the limiting case of the standard toroidal geometry written in terms of the Fock functions.

Noncommutative aspects of Villadsen algebras

Ivanescu, Cristian

The study of C*-algebras is often thought to be the study of noncommutative topological spaces. M. Rieffel introduced stable rank as a noncommutative version of the covering dimension of topological spaces. All simple C*-algebras were thought to be either stable rank one or infinity. J. Villadsen constructed simple C*-algebras with a stable rank equal to 2, 3 , 4 ...In my talk, I will discuss Villadesn's construction and present some recent results on Villadsen algebras obtained in joint work with Dan Kučerovský from UNB.

Coupled system of Dirac fermions with different Fermi velocities via composites of SUSY operators

Jakubský, Vít

Nuclear Physics Institute of CAS, Czech Republic

We use the framework of supersymmetric transformations in the construction of coupled systems of Dirac fermions. Its energy operator is a composite of the generators of the associated superalgebra, and the two coupled Dirac fermions acquire different Fermi velocities. We discuss in detail the peculiar spectral properties of the new system. The emergent phenomena like level crossing or generation of bound states in the continuum (BICs) will be illustrated on an explicit example.

Generalized Coherent states with definite Orbital Angular Momentum

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Joint work with: S. Cruz y Cruz

A group-theoretical approach to the paraxial Helmholtz equation is discussed in order to describe classical optical modes with definite orbital angular momentum (OAM), as superpositions of Laguerre-Gaussian modes solution. By using the factorizing operators as well as their algebraic properties we construct the OAM ladder operators that fulfill either Heisenberg-Weyl or SU(1,1) algebras. These operators, allow to construct Glauber, Barut-Girardello (BG), and Perelomov coherent states. A mechanism to produce BG coherent states in practice will be also proposed. These can be used as a fisrt approach to evaluate spatial correlation in down converted photons with definite OAM.

Covariant Worldline Actions from Coadjoint Orbits and Dual Pair Correspondences

Joung, Euihun

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I will demonstrate how one can derive a manifestly covariant worldline action starting from Poincare and (A)dS algebra. Starting from a coadjoint orbit of the latter algebra and using the Kostant-Kirillov-Souriau symplectic structure on it, we first derive the unconstrained Hamiltonian action on a “curved” phase space, whose quantization would lead to a unitary irreducible representation of the starting Lie algebra. We then reformulate this action as a constrained Hamiltonian action on a “flat” embedding phase space. The set of constraints is in general a mixture of the first and second class constraints, and it defines a new coadjoint orbit of a “dual” symmetry. Upon quantization, this construction provides the reductive dual pair correspondence. I will also briefly comment about this correspondence, a very powerful tool to handle a large class of representations.

Quasiparticle transport in Majorana wire networks: A quantum graphs based approach

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Joint work with: M. Akramov, I. Askerbeyli and D. Matrasulov

Majorana fermsions in low-dimensional condensed matter structures attracted much attention in the context of topological quantum computation and quantum technology. An interesting structure related to Majorana fermions are so-called Majorana wire networks. Majorana fermions are described as quasiparticles which are equivalent to their antiparticles. Recent experiments on condensed matter physics showed that there are some quasiparticles that can "mimic" Majorana fermions. An interesting feature of Majorana fermions in wires or networks is caused by the fact that they correspond to zero energy modes, i.e., are described as zero-energy state of the Bogoliubov de Gennes equation. As a result, they cannot be current-carrying particles. In this work we consider Majorana wire networks which are described in terms of the Bogoliubov de Gennes (BdG) equation on quantum graphs by focusig on unperturbed and driven (by external time-periodic field). Solving BdG equation on metric graphs having different topologies we consider dynamics of Majorana fermions on networks of various architectures. Not only p-wave but also d-wave quasiparticles also considered. For periodically driven case, we analyze time-dependence of the average kinetic energy and average momentum.

Explicit Yang-Baxter operators - constructions and applications

Kirschner, Roland

Institut für Theoretische Physik, Universität Leipzig, Germany

We consider Yangians of $g\ell(n)$ type, the L operators of Jordan-Schwinger form and corresponding Yang-Baxter relations. We discuss several explicit forms of R-operators and applications to Yangian symmetric correlators.

The Kontsevich star-product for affine Poisson brackets: new rational formula

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Johann Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence, University of Groningen, The Netherlands

Noncommutative associative star-products are deformations of the usual product of functions on smooth manifolds; in every star-product, its leading deformation term is a Poisson bracket. Kontsevich's star-products on finite-dimensional affine Poisson manifolds are encoded using $\mathbb{R}$-linear combinations of graphs with ordering of directed edges. Finding the real coefficients of graphs in Kontsevich's star-product expansion is hard in practice; conjecturally irrational Riemann zeta values appear from the firth order onwards. In a joint work with R. Buring (`arXiv:2209.14438` [q-alg]) we obtain the seventh order formula of Kontsevich's star-product for affine Poisson brackets (in particular, for linear brackets on the duals of Lie algebras). We discover that all the graphs near the Riemann "zetas of concern" assimilate into differential consequences of the Jacobi identity, so that all the coefficients in the star-product formula are rational for every affine Poisson bracket.

Embedding formalism for $\mathcal{N}$-extended AdS superspace in four dimensions

Koning, Nowar

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Anti de Sitter (AdS) superspaces arise as maximally supersymmetric solutions to supergravity theories. Supertwistors provide a natural framework for describing AdS superspaces due to their transformation properties under the AdS supergroup. In this talk I will discuss the supertwistor and bi-supertwistor realisations of $\mathcal{N}$-extended AdS superspace in four dimensions, and describe the superspace geometry via the corresponding coset construction.

On Yangian deformations of some $\mathcal{S}$-commutative quantum vertex algebras

Kožić, Slaven

Department of Mathematics, Faculty of Science, University of Zagreb, Zagreb, Croatia

In this talk, we consider a certain new class of quantum vertex algebras associated with the Yang R-matrix. They are obtained as Yangian deformations of some $\mathcal{S}$-commutative quantum vertex algebras and their $\mathcal{S}$-locality is of the RTT-form. We will present some preliminary results on their representation theory and their braiding map. In particular, we will show that its fixed points are closely related with Bethe subalgebras in the Yangian quantization of the Poisson algebra $\mathcal{O}(\mathfrak{gl}_N((z^{-1})))$, which were recently introduced by Krylov and Rybnikov. Finally, we will discuss possible generalizations of some of these results to the case of the trigonometric R-matrix in type A. This is a joint work with Lucia Bagnoli.

Symmetries of gerbes and prequantization

Krepski, Derek

Department of Mathematics, University of Manitoba, Winnipeg, Canada

Let M be a smooth manifold, and let $\chi \in \Omega^3(M)$ be a closed differential form with integral periods. The infinitesimal symmetries of an S^1-bundle gerbe over a manifold M form a Lie 2-algebra. Modelling these symmetries using multiplicative vector fields, the natural notion of infinitesimal symmetry for Lie groupoids, this talk relates the infinitesimal symmetries of S^1-bundle gerbes, with underlying 3-curvature χ, to three Lie 2-algebras naturally associated with (M, χ): the Poisson Lie 2-algebra of observables, the Lie 2-algebra of sections of the Courant algebroid, and the Atiyah Lie 2-algebra .

Exact gauge fields from anti-de Sitter space

Kumar, Kaushlendra

IRIS Adlershof, Humboldt University Berlin, Germany

In 1977 Lüscher found a class of SO(4)-symmetric SU(2) Yang–Mills solutions in Minkowski space, which have been rederived 40 years later by employing the isometry $S^3 \cong \mathrm{SU}(2)$ and conformally mapping SU(2)-equivariant solutions of the Yang–Mills equations on (two copies of) de Sitter space $\mathrm{dS}_4 \cong \mathbb{R}\times S^3$. Here we present the noncompact analog of this construction via $\mathrm{AdS}_3 \cong \mathrm{SU}(1,1)$. On (two copies of) anti-de Sitter space $\mathrm{AdS}_4 \cong \mathbb{R}\times\mathrm{AdS}_3$ we write down SU(1,1)-equivariant Yang–Mills solutions and conformally map them to $\mathbb{R}^{1,3}$. This yields a two-parameter family of exact SU(1,1) Yang–Mills solutions on Minkowski space, whose field strengths are essentially rational functions of Cartesian coordinates. Gluing the two AdS copies happens on a dS_3 hyperboloid in Minkowski space, and our Yang–Mills configurations are singular on a two-dimensional hyperboloid $\mathrm{dS}_3 \cap \mathbb{R}^{1,2}$. This renders their action and the energy infinite, although the field strengths fall off fast asymptotically except along the lightcone. We also construct Abelian solutions, which share these properties but are less symmetric and of zero action.

Conformal Symmetry in the Bhabha Theory

Kuwata, Seichi

Graduate School of Information Sciences, Hiroshima City University, Japan

The first-order formalism of relativistic wave equations, such as the Dirac (spin 1/2) and the Kemmer (one 1) equations, are generalized to the Bhabha (one s) equation. In four space-time dimensions, the irreducibility of the generalized Gamma matrices labels them two parameters s_1 and s_2, such that $s_1 + s_2 = s$ and that $2s_2 = 0, 1, \ldots, \lfloor s \rfloor$. We show that for $s_2 = 0$, the generators $(\Delta, \pi_\mu, \kappa_\mu, s_{\mu\nu})$ constructed from the generalized Gamma matrices satisfy the conformal algebra, in which we find that the null-eigenstates $|s_\pm\rangle$ with respect to π_μ and κ_μ as $\pi_\mu|s_+\rangle = 0 = \kappa_\mu|s_-\rangle$ have the following properties: $\mathrm{Rank}\, P_\pm = 2s+1$ $(P_\pm|\psi\rangle = |s_\pm\rangle)$ and $\hat{s}^2|s_\pm\rangle = s(s+1)|s_\pm\rangle$, where $\hat{s}$ represents the spin magnitude. In this sense, we can regard the state $|s_\pm\rangle$ as physical for a massive particle.

The $\mathbb{Z}_2^2$-graded $1D$ superspace with exotic boson

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In the worldline $\mathbb{Z}_2^2$-graded superspace an extra, exotic bosonic coordinate is present. The graded superspace calculus implies that this extra coordinate defines a second direction. As a result, the $\mathbb{Z}_2^2$-graded worldline super-Poincaré algebra induces two-dimensional $\mathbb{Z}_2^2$-graded relativistic models. These models are invariant under a $2D$ $\mathbb{Z}_2^2$-graded super-Poincaré algebra which differs from the two previous $2D$ $\mathbb{Z}_2^2$-graded versions that were considered in the literature. The talk is based on the paper Nucl. Phys. B 991 (2023) 116202 whose coauthors are N. Aizawa, R. Ito and F. Toppan).

Relaxed category and vanishing of cohomology associated to quantum reduction

Kwon, Namhee

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We introduce a subcategory of the relaxed category over an affine Lie superalgebra. This subcategory, called the adapted relaxed category in this paper, is motivated from the generalized Verma modules defined in [V. G. Kac and M. Wakimoto, Adv. Math., 185, 400 (2004)]. In the adapted relaxed category, we construct a certain generalized Verma module which plays similar roles to a projective cover in the Bernstein-Gelfand-Gelfand category. Using this generalized Verma module, we prove the vanishing property of cohomology associated to quantized Drinfeld-Sokolov reduction in the adapted relaxed category.

Deformation of smooth surfaces along a curve

Lee, Hyun Chol

RINS Gyeongsang National University, Jinju, Korea

We study the connection of smooth parameter surfaces along closed curves. Finds the algebraic properties of the curve for surface connections. Our surface connection method can be used as a method of smoothly transforming a surface in a general area rather than a rectangular area.

Separation of variables and correlation functions from spin chains to CFT

Levkovich-Maslyuk, Fedor

Institut de Physique Theorique CEA Saclay, Gif-sur-Yvette, France

I will present recent progress in the application of the separation of variables (SoV) method in quantum integrable models. In particular, I will describe the construction for gl(N) integrable spin chains. By finding, for the first time, the matrix elements of the SoV measure explicitly I will show how to compute various correlation functions and wave function overlaps in a simple determinant form. I will also demonstrate the power of SoV in 4d integrable CFT's such as the fishnet theory, and present related results for Yangian symmetry of a new large class of Feynman graphs in these models. Lastly I will outline highly promising applications in computation of exact correlators in N=4 super Yang-Mills theory.

Positive mass gap of Yang-Mills fields

Lim, Adrian

Singapore Institute of Technology, Singapore

We will describe a countable sum of separable Hilbert spaces, each indexed by an irreducible representation ρ of a simple Lie Algebra $\mathfrak{g}$, of a compact Lie gauge group. Each state in each component Hilbert space is given by a double, a space-like rectangular surface $S \subset \mathbb{R}^4$, with a measurable section of $S \times [\rho(\mathfrak{g}) \otimes \mathbb{C}] \to S$ defined on it. The inner product is associated with the area of the surface S, and we will explain how $\mathrm{SL}(2, \mathbb{C})$ defines an infinite dimensional unitary representation on this Hilbert space. Take the average trace of a Yang-Mills path integral involving the $\rho(\mathfrak{g})$-valued curvature squared, taken over a time-like rectangular surface, gives us the momentum eigenvalue squared. It is equal to the quadratic Casimir operator, minus off a positive term. By defining the Hamiltonian eigenvalue squared to be this Casimir operator, we see the existence of a positive mass gap in each component Hilbert space. The mass gap goes to infinity as the Casimir operator increases to infinity, concluding that a positive mass gap exists on this 4-dimensional quantum gauge theory.

Measuring Three-qubit Entanglement in the Smallest Eigenvalue Space

Luna-Hernández, Salvio

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Although multipartite entanglement is crucial in quantum information, its characterization is nontrivial in general. The entanglement polytope is very useful in this regard since, compared with other characterizations of entanglement like the full tomographic reconstruction, it requires just a few sets of resources. Using such a formulation, the entanglement of a three-qubit system is studied in connection with geometric elements of a polytope and two different measures that involve local information only.

Weyl-Grönewald-Moyal quantization of algebraic spaces

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The problem of deformation quantization of the singular surfaces is in the focus. For several examples of singular Poisson spaces, convergent Grönewold-Moyal star product series is explicitly constructed.

On some generalization of Gleason theorem

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The Generalized Gleason Theorem states that for any von Neumann algebra M with no direct summand of type I_2 and any Banach space X each bounded X-valued measure μ on the projection lattice of M extends uniquely to a bounded linear operator from M to X. We consider the case when X is another von Neumann algebra N and μ is a positive measure. Then naturally μ extends to a positive map $\phi : M \to N$. We are focused on the following two problems:

- What is the type of continuity of the map ϕ depending on the properties of μ?
- Is it possible to characterize the type of positivity of ϕ such as k-positivity, complete positivity, decomposability, etc. in terms of the measure μ?

It turns out that in both problems rank properties of the measure μ play crucial role. One of the main results states that the map ϕ is completely positive if and only if μ lies in the convex cone generated by morphisms between projection lattices of M and N.

Algebraic superintegrability from commutants: classical and quantum aspects

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Joint work with: Rutwig Campoamor-Stursberg, Danilo Latini and Yao-Zhong Zhang

It was discovered how polynomial algebras appear naturally as symmetry algebra of quantum superintegrable quantum systems. They provide insight into their degenerate spectrum, in particular for models involving Painlevé transcendents for which usual approaches of solving ODEs and PDEs cannot be applied. Those algebraic structures extend the scope of usual symmetries in context of quantum systems, but they also been connected to different areas of mathematics such as orthogonal polynomials. Among them, the well-known Racah algebra which also admit various generalisations. Here we will take a different perspective on those algebraic structures which is based on a purely algebraic procedure. We will rely on the commutant of a subalgebra in the universal enveloping algebra of a given Lie algebra, the notion of algebraic Hamiltonians and the constants of the motion generating a polynomial symmetry algebra is proposed. The case of the special linear Lie algebra $\mathfrak{sl}(n)$ is discussed in detail, where an explicit basis for the commutant with respect to the Cartan subalgebra is obtained, and the order of the polynomial algebra is computed. It is further shown that, with an appropriate realization of $\mathfrak{sl}(n)$, this provides an explicit connection with the generic superintegrable model on the $(n-1)$-dimensional sphere $\mathbb{S}^{n-1}$ and the related Racah algebra $R(n)$. In particular, we show explicitly how the models on the 2-sphere and 3-sphere and the associated symmetry algebras can be obtained from the quadratic and cubic polynomial algebras generated by the commutants defined in the enveloping algebra of $\mathfrak{sl}(3)$ and $\mathfrak{sl}(4)$ The talk is based on Campoamor-Stursberg, Latini, Marquette, Zhang, Algebraic (super-)integrability from commutants of subalgebras in universal enveloping algebras, J.PhysA Math. and Theor. (2023) arXiv:2211.04664

Design of new control loop with Hysis dynamics

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Joint work with: Khebli, Abdelmalek

In the same way pressure is also critical to the good conduct of the process, a drift in a parameter can affect the efficiency of the expander or the outlet temperature of the gas, consequently this will have impact on the extraction of liquids. Due to the unsatisfactory performances of the existing control loop, we have been proposed to design a new loop which will meet most of the requirements needed to maintain good rates of liquids extraction and to ensure maximum availability and reliability of the turbo-expander. In addition to the development of a DCS based control System, good continuous control is needed to maintain some parameters at desired values, these parameters are mainly machine speed and pressure trough it (at the inlet or at the outlet, it depends on the purpose). Machine speed is critical for good performances and availability of the turbo-expander, 'over speed' is a trip factor which shuts down the machine and causes production loss (as explained in the second chapter) and speeds above the design operational value can cause troubles with lube oil and bearings température, in addition to this, 'excessive vibrations' which is also a trip factor results, from oscillatory behavior of the different parameters. The design was based on the simulation models offered by the powerful petrochemicals and gas equipment simulator: ASPEN HYSYS. The high fidelity and flexibility of the software in addition to its dynamic simulation mode have motivated us to select it among the existing simulators in the market. Detailed explanations and descriptions will be given along this chapter to show the steps which had led us to the results.

Realizations of the Yang model

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Many years ago, C.N. Yang proposed a model of noncommutative geometry in curved space, based on the algebra $so(1,5)$. We discuss some aspects of it, and in particular its realization in terms of phase space variables.

Integrable vortices on compact Riemann surfaces of genus one and two

Miyamoto, Kaoru

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Joint work with: A. Nakamula

Abelian vortices are two-dimensional topological solitons, solved exactly in the case that the coupling constants take critical values. The Jackiw-Pi vortices are one of these integrable vortices which correspond to maps from the Euclidean plane into the Riemann sphere. In this talk, we study the Jackiw-Pi vortices on a torus in terms of various elliptic functions. We give representations of the vortices with Jacobi theta functions and reconsider the calculation for the determination of the vortex number. We also consider the Ambjorn-Olesen vortices defined on the hyperbolic plane. By constructing with specific automorphic functions, we can regard them as the vortices on compact $g \geq 2$ surfaces.

Doubled Structures of Algebroids in Gauged Double Field Theory

Mori, Haruka

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Joint work with: Sasaki, Shin

Double field theory (DFT) is an effective theory of string theory. It has a manifest symmetry of T-duality. The gauge symmetry in DFT is related to some kind of algebroid structures, and they have a doubled structure. In this talk, we focus on the gauge algebra of the $O(D, D+n)$ gauged DFT and discuss an extension of the doubled structure. The gauge algebra of the $O(D, D+n)$ gauged DFT has been described by the twisted C-bracket. This bracket is related to some algebroid structures. We show that algebroids defined by the twisted C-bracket in the gauged DFT are built out of a direct sum of three (twisted) Lie algebroids. They exhibit a "triple", which we call the extended double, rather than a "double" structure. We also consider the geometrical realization of these structures in a $(2D+n)$-dimensional manifold.

Categorical low-energy effective field theory of neutron beta decay

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Joint work with: H. Abele

We introduced Feynman categories as a universal foundational framework for treating operations and their relations in the low-energy effective field theory of neutron beta decay, on the one hand. Our definition of a Feynman category gives a connection to Feynman diagrams which is responsible for the terminology. In our setup the graphs are crucially the morphisms and not the objects. Having encoded the theories in this fashion, we can make use of categorical tools, such as Kan-extensions. This enables us to define pull-backs, push-forwards (left Kan extensions), which are always possible as well as extension by zero (right Kan extension) which sometimes exist, et cetera. Indeed we show that all classical constructions, such as free objects, the PROP generated by an operad, the modular envelope, etc., are all push-forwards. To further extend the applicability to the low-energy effective field theory of neutron beta decay, we also consider the enriched version of the theory. On the other hand, we have studied categorical properties of the low-energy effective field theory of neutron beta decay by applying the method of additional structures on objects of the category of Schrödinger equations too.

Lens partition functions and integrability properties

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We study hyperbolic hypergeometric integral identities acquired via the duality of lens partitions functions for the three-dimensional $N = 2$ supersymmetric gauge theories. We consider integral identites as solutions to the star- triangle relation, the star-star relation, and the pentagon identity via the gauge/YBE correspondence. The correspondence allows the construction of integrable lattice spin models in statistical mechanics by the use of integral identities solving integrability conditions of the spin lattice model. We will also work on dual lattice models of integrable Ising-like models in statistical mechanics by presenting the supersymmetric dualities as the solutions of decoration transformation, the star square relation and the generalized star-triangle relation.

SWKB Quantization Condition and Isochronism in Quantum Mechanics

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The supersymmetric quantum mechanics (SUSY QM) has been extensively investigated for decades. In the context of SUSY QM, a WKB-like quantization condition called supersymmetric WKB (SWKB) condition has been proposed. The quantization condition successfully reproduces the exact bound-state spectra for many of the well-known exactly solvable potentials such as the harmonic oscillator, the Coulomb potential, the Morse potential and the Pöschl–Teller potential. In the other way around, one can reconstruct those potentials by using the SWKB condition, assuming only the knowledge of the explicit forms of their energy spectra. On the other hand, in classical mechanics, it has long been considered how one can construct a class of potentials where the period of oscillation is constant in the total energy, i.e., the construction of isochronous potentials. In this talk, we show how to construct a novel class of solvable quantum-mechanical potentials in the SWKB formalism, taking advantage of a similarity between the SWKB condition and the period of oscillation. How the isochronism appears in quantum-mechanical systems is also discussed.

Realizations and invariants of Lie algebras

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Joint work with: S. Pošta

We study realizations and differential invariants of Lie algebras and their applications. Particular attention is paid to the construction of invariants in polynomial forms and to the realizations that generate them. We also consider the methods for constructing Lie vector fields (realizations) and differential invariants without solving PDEs systems. Several examples based on Euclidian, Galilean and Poincaré algebras are presented, and limiting processes between their differential invariants are discussed.

Non-perturbative Landau-Khalatnikov-Fradkin gauge transformations for the propagator and vertex in QED

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The Landau-Khalatnikov-Fradkin (LKF) transformations describe how the Green functions of a quantum field theory (propagators and vertices) transform under a change in the photon field's linear covariant gauge parameter (commonly denoted by ?). The transformations are framed most simply in coordinate space where they are multiplicative. The non-perturbative nature of these transformations means that we can obtain additional information on gauge-dependent contributions from all higher order diagrams in the perturbative series from lower order contributions, which is useful in multi-loop calculations. We study the LKF transformations for the propagator and the vertex in both scalar and spinor QED, in some particular dimensions. A novelty of our work is to derive momentum-space integral representations of these transformations; our expressions are applicable to the propagator and to the longitudinal and transverse parts of the vertex. Furthermore, applying these transformations to the tree-level Green functions, we are able to give non-perturbative results and show that the oneloop terms obtained from the LKF transformation agree with the gauge dependent parts obtained from perturbation theory. Our results have been summarized in [N. Ahmadiniaz, J. P. Edwards, J. Nicasio, C. Schubert, Phys. Rev. D 104, 025014 (2021)], as well as in various preprints (arXiv:2010.04160, arXiv:2201.12448), and will be presented in an article currently in preparation.

Jordan blocks and the Bethe ansatz: the eclectic spin chain as a limit

Nieto García, Juan Miguel

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I present a procedure to extract generalised eigenvectors of a non-diagonalisable matrix by considering a diagonalisable perturbation and computing the non-diagonalisable limit of its eigenvectors. As an example, I show how to compute a subset of the spectrum of the eclectic spin chain by computing the appropriate limit of the Bethe states of a twisted su(3) spin chain.

Quantum Particle on G_2 Dual Weight Lattice in Even Weyl Alcove

Novotný, Petr

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Model of a free non-relativistic quantum particle propagating on the dual weight lattice inside the scaled fundamental domain is described and solved using Weyl orbit functions. Example concerning G_2 root system is presented.

Title A geometric interpretation of the Peter-Weyl theorem

Nunes, João P.

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Let K be a compact Lie group. I will review the construction of Mabuchi geodesic families of $(K \times K)$–invariant Kähler structures on T^*K, via Hamiltonian flows in imaginary time generated by a strictly convex invariant function on $LieK$, and the corresponding geometric quantization. At infinite geodesic time, one obtains a rich mixed polarization of T^*K, the Kirwin-Wu polarization, which is then continuously connected to the vertical polarization of T^*K. The geometric quantization of along this family of polarizations is described by a generalized coherent state transform that, as geodesic time goes to infinity, describes the convergence of holomorphic sections to distributional sections supported on Bohr-Sommerfeld cycles. These are in correspondence with coadjoint orbits $O_{\lambda+\rho}$. One then obtains a concrete (quantum) geometric interpretation of the Peter-Weyl theorem, where terms in the non-abelian Fourier series are directly related to geometric cycles in T^*K. The role of a singular torus action in this construction will also be emphasized. This is joint work with T. Baier, J. Hilgert, O. Kaya and J. Mourão.

Exploring the behavior of statistical meta-features in meta-models' development

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There have been many algorithms developed in the field of machine learning, which is an active area of study. Different levels of machine learning experts usually struggle with the same issue: which algorithm will work best with their data? Recent meta-learning research automates this process by predicting the optimum algorithm for a given dataset using a meta-classifier. Different categories of meta-features are used to build the meta-classifier and to characterize the properties of datasets. In this research, the impact of statistical meta-features in simulating the interaction between the learning algorithms and the properties of data sets is investigated. Statistical meta-features try to capture the statistical properties of the data. They are used only for numerical attributes and provide information about data distribution: average, standard deviation, kurtosis, and correlation. Research is performed on publicly available data from the social sciences domain: business and education. Results indicated a high level of importance for statistical meta-features in identifying optimal machine learning algorithms in social science data analysis.

Coherent states generated by means of supersymmetric quantum mechanics for tilted anisotropic Dirac materials

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Joint work with: Erik Díaz-Bautista

In this paper, we consider the interaction of electrons in tilted anisotropic Dirac materials with external electric and magnetic fields with translational symmetry. Then, the eigenstates and eigenvalues for the corresponding Hamiltonian operator can be obtained by means of the supersymmetric quantum mechanics. In order to use a semi-classical approach to analyze this system, we find a family of coherent states. Finally, the properties of these states are analyzed through fidelity and the Wigner function.

Quantum Motion Algebra

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Joint work with: A. Góźdź

A notion of Quantum Motion Algebra (QMA) allows to construct quantum space for different physical systems moving under a given group of motion. The main idea of QMA is a construction of a group algebra with involution generated by a group of motion G. After defining a linear and nonnegative functional on this algebra one can use the Gelfand-Naimark-Segal construction to construct the appropriate quantum state space. The QMA method can be applied in modeling physical systems requiring additional degrees of freedom. During my talk I will present an example QMA application in a model of nuclear collective pairing where the nonnegative functional is defined by temperature dependence density operator.

Finite W-superalgebras and super Yangians

Peng, Yung-Ning

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In this talk, we will first recall a remarkable connection between type A finite W-superalgebras and super Yangians. More precisely, there is an isomorphism from a quotient of a certain subalgebra of the Yangian, called the *shifted Yangian*, to the corresponding finite W-superalgebra of a general linear Lie superalgebra. In the non-super setting, the relations between these two objects were firstly observed by Ragoucy-Sorba for some special case, where the general case was established by Brundan-Kleshchev. We will explain some difficulties appearing in the super setting and how to overcome them by making use of the notion of 01-sequence. This talk is based on the paper [Adv. Math. 377 (2021) 107459].

Classical conformal blocks, Coulomb gas integrals and Richardson-Gaudin models

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Institute of Physics, University of Szczecin, Szczecin, Poland

In the talk the so-called Richardson solution of the reduced BCS model, its relation to the Gaudin model, and a known conformal field theory realization of these models will be discussed. The CFT techniques applied to solve the Richardson-Gaudin (RG) model are based on the use of the free field realization, or more precisely, on the calculation of saddle-point values of Coulomb gas integrals representing certain (perturbed) WZW conformal blocks. It turns out that the saddle-point approximation is nothing but the classical limit of conformal blocks. On the one hand, this observation implies a new method for calculating classical conformal blocks. On the other hand, these tools can be used to study the spectrum of the RG model and the entire class of models of this type, integrability of which is based on the relationship with the Knizhnik-Zamolodchikov equation. Moreover, it seems that realizations within 2d CFT have also other quantum integrable systems, e.g., the elliptic Calogero-Moser model, and within such representations spectra of these models can be calculated. The talk is based on the paper [JHEP04(2022)098].

Title Quantum $3j$-symbols for $U_q(sl_3)$

Pichai, Ramadevi

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Joint work with: Ayaz Ahmed and Shoaib Akhtar

We propose an algebraic expression for $U_q(sl_3)$ quantum $3j$ symbols (quantum Clebsch-Gordan coefficients) appearing in the decomposition of tensor product of symmetric representations. Our compact form will be useful to write the spectral parameter dependent R-matrix elements for any bi-partite vertex model whose edges carry states of the symmetric representations.

Interbasis expansions for the eigenfunctions of Laplace-Beltrami operator on two-dimensional hyperboloid and contractions

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Joint work with: Alexandre Yakhno

In this report we present some results of our recent investigation of the Lie algebra contractions and separation of variables for the two-dimensional Laplace-Beltrami equation on two-sheeted two-dimensional hyperboloid (real Lobachevsky space). We present normalized wave functions for all separated coordinates and some interbasis expansions for both subgroup and non-subgroup bases. We also consider contractions from the hyperboloid to the Euclidean plane.

On a parametrically perturbed Kardar-Parisi-Zhang equation of spin glasses theory, its integrability and related thermodynamic stability

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Joint work with: M. Vovk and P. Pukach

Amongst the revealed new universally behaving stochastic systems we meet such important ones as directed polymers in random media and spin glasses, whose characteristic thermodynamic parameters display non-Gaussian limiting distributions and described by means of the well known [?] Kardar-Parisi-Zhang equation:

$$\partial v/\partial t = \partial^2 v/\partial x^2 - u(\partial v/\partial x)^2/2 := K[v,u], \tag{1}$$

representing a new universality class – the KPZ universality class, where $u(x,t$ is a parameter, which can often be (heuristically) computed for a particular growth model directly from the microscopic dynamics, specified by a statistical physics model under regard. What is here worth to mention, the parametrically generalized spin glass growth KPZ equation (1) makes it possible to look at its thermodynamics from the optimal control problem approach, thus creating an opportunity to control the spin glass growth process and its thermodynamic stability. To analyze this problem, we made use of gradient-holonomic algorithm [?] and demonstrated that the parametrically extended Kardar-Parisi-Zhang system of equations

$$v_t = v_{xx} - \; uv_x^2/2, u_t \; = -u_{xx} \; - \; (u^2 v_x)_x/2 \tag{2}$$

on the combined functional manifold $M_v \times M_u$ is completely integrable and possesses an infinite hierarchy of the conserved quantities, providing thermodynamically stable spin glass growth process. There are also presented some results on a more physically grounded KPZ model

$$v_t = (pv_x)_x - \ uv_x^2/2 \tag{3}$$

with an additional diffusion coefficient parameter $p \in M_p$, possessing at some temporal evolution constraints on the functional parameter $u \in M_u$ a finite number of conservation laws.

Supersymmetric Quantum Mechanics Formalism in a Modeling for Protein Folding

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Joint work with: E. Drigo Filho, Jorge Chahine and Marcelo Tozo Araujo

Proteins are structures formed by chains of amino acids. In the unfolded state the protein is in a linear configuration of amino acids and is synthesized in a folded three-dimensional structure to perform specific functions in the organism. To reach this final structure, this linear sequence can pass through intermediate conformations to become functional. Recently, a mathematical method was developed to analyze the folding process, by considering it as a diffusion process, described by the Fokker-Planck equation (FPE). The FPE is mapped to a Schrödinger type equation and the algebraic method of Supersymmetric Quantum Mechanics associated with the variational method is applied to obtain the approximate spectrum of the SE and consequently solve the FPE. This allows the construction of the temporal evolution of the probability density function $P(x, x_0, t)$. Thus, a symmetric tri-stable free energy function V(x) was chosen to describe the unfolded, folded and an intermediate state of the protein. The diffusion process is characterized by calculating the particle population of the wells in terms of probability. This work presents results considering the asymmetric free energy profiles, generated by mapping the simulation parameters of real proteins.

Two Misconceptions that hinder quantum interpretation

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In our view, two misunderstandings obstruct the advance of quantum theory.

1) The Schrödinger equation, the Dirac equation, the Plank-Einstein equation, Hamilton-Jacobi equation and other formulas form the backbone of quantum mechanics. Functional analysis, infinite-dimensional Hilbert spaces, spectral theory, C*-algebra and additional formal tools enable the calculus of phenomena that otherwise turn out to be unintelligible. Significant advances in quantum physics have been achieved using exclusively mathematical instruments and some physicists believe that the calculus of probability also offers valuable aid to quantum theorists; but this opinion is disputable for the following reason.

For three centuries, scholars have progressively discovered the multifaceted nature of probability, which has opposite characteristics: P is objective and subjective, empirical and logical, epistemic and ontological, practical and abstract, and so on. Despite this complex landscape, each master (say Laplace, von Mises, Keynes, de Finetti and others) develops one model of P and rejects the others. Each master confines himself to one side of P and is convinced that he formulates the 'true' or 'authentic' concept of probability. This controversial intellectual position can be summarized in the following terms: one interpretation (or two at most) of P is sufficient. As a consequence of this position which denies the multifold nature of probability, the scientific community has a dozen irreconcilable theories. Frequentists, subjectivists, Bayesians, logicians and other schools propose frameworks that underpin incomparable perspectives and sometimes add difficulties to QM. For example, the statistical interpretation of the wavefunction was first introduced by Max Born and later extended by the ensemble interpretation. In contrast, the wavefunction encodes the agent's belief about future experiences for followers of the quantum-Bayesian school.
Some propose more axioms in probability theory and neglect that probabilists often use 'tacit axioms,' which are, for example, the notions of initial conditions, random event, and outcome. These notions are given as intuitive even though they are quite complicated and far from self-explanatory.

2) When physicists explore a new field, they begin with experimental observations; they identify and describe the involved elements; and finally translate the shared understanding into the mathematical language. Scientists use the definitional formula (DF) of the physical quantity x which has the special quality to describe the inherent nature of x, and the computational formula (CF) which describes an aspect of x or provides further insights into x, but does not state the basic qualities of x. For example, Ohm's law provides the electric current of circuits, but only $I = (dQ/dt)$ makes explicit the intrinsic nature of I that is the rate of electric charge flowing through a conductor. Let us question whether the wavefunction is appropriate for the purpose of establishing the nature of quantum waves.
The wavefunction is the solution to the Schrodinger equation, which is symmetrical to classical criterion of energy conservation. The *time-dependent* Schrodinger equation describes a system evolving with time, while the *time-independent* equation predicts stationary waves. All this is sufficient to conclude that Ψ and Φ which derive from the Schrodinger equation, are typically CFs. They are not definitional; in fact, ample literature still debates whether the wavefunction is real, how can be measured etc. If the wavefunction were definitional, it would answer these questions with precision.

In a rather paradoxical manner, we conclude that QM must define the objects under investigations that are waves and particles. Classical authors such as Karl Popper and modern authors such as Andrei Khrennikov, advocate that the comprehensive probability theory should underpin the fundamental arguments of quantum mechanics. We shared this criterion of work and by the end of the past century we initiated a theoretical inquiry whose first phase developed a construction that embraces all the probability interpretations and addresses hitherto neglected indeterminate phenomena. The second phase has imported these mathematical results into QM [1].

In particular, it formulates *quantum waves and particles as indeterminate and determinate statuses of energy/matter* respectively. Basically, the concept of wavefunction and indeterminate status clarify and formally complete each other. The theory focuses on the indeterminate status which continues in the same condition until the wave moves freely. As soon as the movement is no longer free due to an interfering external factor, the theory forecasts that the wave becomes determinate, namely it collapses. Measurement process is the most common material factor, but other physical factors can also interrupt the free flight.
The new theorems on probability cover both the macroscopic and microscopic worlds. They offer symmetrical views of the classical and quantum physics; therefore, they can be regarded as a bridge connecting CM and QM, and provide an original answer to the long-standing question about the relationship between the classical and quantum environments.

(1) P. Rocchi (2023) *Probability, Information and Physics: Problems with quantum mechanics in the context of a novel probability theory*, World Scientific..

Negative radiation pressure in soliton dynamics

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Solitons in many aspects can be treated as small compact objects which can interact with each other and their surroundings. As usual particles they can experience for example radiation pressure. Surprisingly, some solitons undergo negative radiation pressure. During the talk I will make a review of a few mechanisms that can cause this counterintuitive effect and discuss its physical consequences.

Tunneling for a semi-classical Schrödinger operator with symmetries

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We consider a semi-classical quantum particle in a magnetic field $A(x)$ and an external potential $V(x)$. The underlying classical system, symplectic structures and their symmetries play an important role in investigating tunneling properties.
Our first main result concerns the operator $P_A(x, hD_x) = (hD_x - \mu A(x))^2 + V(x)$ on $L^2(\mathbf{R}^d)$ when V has two non degenerate potential wells symmetric with respect to an hyperplane. We study the low-lying eigenvalues of $P_A(x, hD_x)$ and estimate their splitting with an exponential accuracy. This splitting is related with the decay of eigenfunctions in the classically forbidden region, and bounded from above by Agmon estimates. Standard Agmon estimates are based on the exponential decay of the eigenfunctions along the minimal geodesics γ between the wells, relative to the degenerate Agmon metric $ds^2 = (E - V(x))_+ \, dx^2$. For μ large enough, we can improve in certain cases these estimates by including the correction due to the magnetic field. Our argument relies first

on an integral formula by R.Lavine and M.O'Carroll (1977) reflecting the fact that the classical motion can be approximately decoupled into a cyclotronic motion, driven by the magnetic potential, and a magnetic drift, due to the scalar potential. This holds when $dA(x) = 0$ near the set of minimal geodesics γ, or at least when γ stays close enough to a magnetic line, which can be the case when $d = 3$ and $A(x) = (-x_2, x_1, 0)$. The proof then involves solving some Hamilton-Jacobi equation in the class of Lipschitz functions. Our second result is related to phase-space tunneling for $P_A(x, hD_x) = (hD_x - A(x))^2$ on $L^2(\mathbf{T}^2)$. We consider the situation where the classical Hamiltonian $P_A(x, \xi) = (\xi - A(x))^2$ is integrable on the symplectic manifold $(T^*\mathbf{T}^2, \sigma_B)$ endowed with the magnetic 2-form $\sigma_B = \sigma + B$, where $B = dA$. This occurs iff $B(x) \neq 0$ and the differential of $A(x)$ has determinant 1. Using global action-angle coordinates (I, φ), semi-classical quantization holds within the standard magnetic h-Pseudo-differential Weyl Calculus. σ_B-Lagrangian invariant tori satisfying EBK quantization rule carry quasi-modes for $P_A(x, hD_x)$. Assuming that $A(-x) = -A(x)$, there is a family $\Lambda_\pm(I)$ of Lagrangian invariant tori given by $I =$ Const. and such that $\Lambda_-(I) = -\Lambda_+(I)$. When $I \neq 0$, $\Lambda_\pm(I)$ are separated in phase-space. Moreover if $A(x)$ has analytic coefficients, they generically extend to a single complex σ_B-Lagrangian manifold $\Lambda(I)$. A loop Γ on $\Lambda(I)$ that connects $\Lambda_\pm(I)$ and has minimal value of the integral of the Kähler 1-form is called a tunnel cycle. The tunnel cycle gives the decay of the quasi-modes in the classically forbidden region, and hence the corresponding splitting of eigenvalues. This is the magnetic analogue of the "tunneling over the potential barrier" in the case of a Schrödinger operator without a magnetic potential on $L^2(\mathbf{T}^2)$.

The Bethe Ansatz as a Quantum Circuit

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In this talk, we share our progress in realising quantum-integrable systems as quantum circuits. We propose the quantum circuit of quantum-integrable spin chains which have a $\mathfrak{u}(1)$-symmetry. Our research presents the quantum gates that construct the Bethe states of these models. In the free-fermion limit of the quantum circuit, quantum gates efficiently decompose into one- and two-qubit gates. We conclude with prospects on future research.

Integrable local and nonlocal spin systems

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Integrable spin systems with potential are of great interest from the point of view of theoretical and applied physics. They make it possible to obtain accurate analytical solutions and study the properties of solitons - nonlinear wave structures that can be stable and move without distortion. The study of solitons in spin systems is of great importance not only for developing new methods for transmitting and processing information but also for developing spintronics and magnetoelectronics in general. These areas of technology are based on the use of the properties and control of the spin moment of electrons. Understanding and controlling spin dynamics in various systems opens up new possibilities for creating more efficient and powerful devices such as magnetic memories, spintronic transistors, and logic elements. This paper considers PT symmetry in spin systems, which refers to invariance under parity and time-reversal transformations. Unique properties of integrable spin systems in PT-symmetric media are highlighted. Implications for quantum information processing and simulation are discussed. These systems hold promise for advanced spin-based technologies and quantum information processing. Further research in this field will uncover new insights and practical applications in quantum technologies.

A New Approach to Quantum Fields: Category Algebras and States on Categories

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We propose a new approach to investigate quantum fields in terms of category algebras and states on categories. We regard the spacetime as a category rather than just a structured set of events, and the observable algebra as a convolution algebra over that category, i.e., a category algebra. Conceptual relationships with conventional approaches to quantum fields, including Algebraic Quantum Field Theory (AQFT) and Topological Quantum Field Theory (TQFT), are also discussed. The framework would be applicable to any system that has both causal structures and (noncommutative) probabilistic structures.

Toward black hole QNM spectrum from quantum spacetime deformation

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Black holes (BH) are predicted by the theory of general relativity as the result of a gravitational collapse of massive astrophysical objects. Among other interesting properties of black holes is a property that they exist in a state of constant arousal. Indeed, realistic black holes can never be fully described by their basic parameters, as they are alw ays in a state of perturbation. Black hole perturbation is followed by a ringdown phase which is dominated by quasinormal modes (QNM). These modes may provide key signature of the gravitationalw aves. During the ringdown phase, black holes gradually relax from the initial perturbation by emitting gravitational waves. Notably, the presence of a deformed spacetime structure may distort this signal. We utilise the methods of noncommutative geometry in order to devise appropriate physical models that are able to account for such effects. In this presentation I will review what has been done so far in this research and expose some prospects for a future work.

Complex Structures, T-duality and Worldsheet Instantons in Born Sigma Models

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Joint work with: Tetsuji Kimura and Kenta Shiozawa

We investigate doubled (generalized) complex structures in $2D$-dimensional Born geometries where T-duality symmetry is manifestly realized. We show that Kähler, hyperkähler, bi-hermitian and bi-hypercomplex structures of spacetime are implemented in Born geometries as doubled structures. We find that the Born structures and the generalized Kähler (hyperkähler) structures appear as subalgebras of bi-quaternions and split-tetra-quaternions. We then study the T-duality nature of the worldsheet instantons in Born sigma models. We show that the instantons in Kähler geometries are related to those in bi-hermitian geometries in a non-trivial way.

Processes with zero-range interaction and integrability

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Zero-range processes are interacting particle systems where particles hop between the lattice sites with rates that depend solely on the number of particles of the departure site. The behaviour on the long wavelength and time-scale of zero-range processes have been extensively studied, and asymptotic results such as hydrodynamic scaling limit, central limit theorem, or large deviations of the empirical distribution of particles have been established. A specific zero-range process on the 1-dimensional infinite lattice, the q-Boson system, was introduced by Sasamoto and Wadati. The q-Boson specifies that a single particle leaves a site at a rate equal to $[n]$, the q-integer of the site occupancy n. Notably, the q-Boson was shown to be integrable in the sense that a class of eigenfunctions can be constructed for the Hamiltonian of the process. Also, several authors (Korhonen and Lee, 2013, Borodin, Corwin, Petrov, and Sasamoto 2014) showed that the transition probabilities can be computed exactly . Later the q-Boson was generalized by Takeyama to a q-Block using the algebra structure generated by the multiplication and divided-difference operators of Lascoux and Schützenberger. The q-Block is totally asymmetric, exhibits zero-range interaction, and has the novel feature that any number of available particles can leave the site. We show that the system of Takeyama can be enhanced to allow the movement of particles to both left and right and remain integrable. Also, we discuss the attractiveness and propose that the hydrodynamic scaling limit of the system is a first-order quasilinear partial differential equation.

Mock-integrability and stable solitary vortices

Sawado, Nobuyuki

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Joint work with: A. Nakamula, K. Obuse, K. Shimasaki, K. Toda

Localized soliton-like solutions to a (2+1)-dimensional hydro-dynamical evolution equation called the Williams-Yamagata-Flierl equation are studied numerically. Although the equation does not have an integrable structure in the ordinary sense, we find there exist shape-keeping solutions with an extraordinarily long life. As for the indicator of the long-term stability of localization, we propose a concept of configurational entropy. Several intrinsic effects cooperate the longevity, and in this talk, we shall describe the mechanism in detail.

Algebraic and symplcetic geometry in the description of quantum correlations

Sawicki, Adam

Center for Theoretical Physics, Polish Academy of sciences

In this talk I will discuss how algebraic and symplectic geometry methods can be used to better understand quantum correlations. Moreover, I will show that for some important quantum information problems they greatly simplify the way of getting a solution.

Quantum Toda Lattice: A Challenge for Representation Theory

Semenov-Tian-Shansky, Michael

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Quantum Toda lattice may solved by means of the Representation Theory of semisimple Lie groups, or alternatively by using the technique of the Quantum Inverse Scattering Method. A comparison of the two approaches,sheds a new light on Representation Theory and leads to a number of challenging questions.

Nonlinear supersymmetric general relativity theory

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The geometrical argument of the general relativity principle of Einstein is formulated in unstable Riemann space-time just inspired by the nonlinear representation of supersymmetry, which produces new Einstein-Hilbert type action(*Nonlinear Supersymmetric General Rerativity Theory(NLSGR)*) composed of Nambu-Goldstone fermion(*superon*), the graviton and the cosmological term. The universal attractive gravitational force would produce the massless superon-composites corresponding to the eigenstates of the irreducible representation of SO(N) super-Poincare' algebra of space-time symmetry. We show by linearizing NLSUSY in the toy model that the standard model(SM) of the low energy particle physics can emerge in the true vacuum of NLSGR as the NG fermion(superon)-composite eigenstates of LSUSY super-Poincare algebra of asymptotic space-time symmetry. NLSGR paradigm can bridge naturally the cosmology and the low energy particle physics and provides new insights into unsolved problems, e.g. the space-time dimension four, the origin of SUSY breaking, the dark energy and dark matter, the dark energy density (neutrino mass)4, the tiny neutrino mass, the three-generations structure of quarks and leptons, the rapid expansion of space-time, the magnitude of the bare gauge coupling constant and he picture of black hole etc.. The superalgebra for the highest spin massless supermultiplet with the helicity (5/2,.3) in N=10 NLSGR is discussed on-shell.

Machine Learning Study through Physics-Informed Neural Networks: Analysis of the Stable Vortices in Non-Linear Field Theories

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Joint work with: A. Nakamula, K. Obuse, N. Sawado, K. Toda

he study of stable solitons in higher dimensions is still an open problem though it is highly required in several phenomenological aspects. Unlike the successful one-dimensional cases, the lack of explicit integrability complicates the situation. Machine Learning technology through the Physics-Informed Neural Networks (PINN) may bring us a new perspective on such unsolved issues. The data-driven discovery of partial differential equations enables us to know how far several implicit effects drive the stability of the solutions. We analyze the Zakharov-Kuznetsov equation which is a two-dimensional version of the well-known KdV equation, and also some regularized-long-wave equations.

T-duality relations between hyperkähler and bi-hypercomplex structures

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Joint work with: Tetsuji Kimura and Shin Sasaki

We exploit the doubled formalism to study comprehensive relations among T-duality, complex and bi-hermitian structures (J_+, J_-) in two-dimensional $\mathcal{N} = (2, 2)$ sigma models with/without twisted chiral multiplets. The bi-hermitian structures (J_+, J_-) embedded in generalized Kähler structures $(\mathcal{J}_+, \mathcal{J}_-)$ are organized into the algebra of the tri-complex numbers. We write down an analogue of the Buscher rule by which the T-duality transformation of the bi-hermitian and Kähler structures are apparent. We also study the bi-hypercomplex and hyperkähler cases in $\mathcal{N} = (4, 4)$ theories. They are expressed, as a T-duality covariant fashion, in the generalized hyperkähler structures and form the split-bi-quaternion algebras. As a concrete example, we show the explicit T-duality relation between the hyperkähler structures of the KK-monopole (Taub-NUT space) and the bi-hypercomplex structures of the H-monopole (smeared NS5-brane). Utilizing this result, we comment on a T-duality relation for the worldsheet instantons in these geometries.

Classical and quantum gravity from the axioms of relativistic quantum mechanics

Smilga, Walter

Geretsried, Germany

It is common practice to describe elementary particles by irreducible unitary representations of the Poincaré group. In the same way, multi-particle systems can be described by irreducible unitary representations of the Poincaré group, which are characterised by fixed eigenvalues of two Casimir operators corresponding to a fixed mass and a fixed angular momentum. In multi-particle systems (of massive spinless particles), fixing these eigenvalues leads to correlations between the particles. In the quasi-classical approximation of large quantum numbers, these correlations take on the structure of a gravitational interaction described by the field equations of conformal gravity. A theoretical value of the corresponding gravitational constant is calculated. It agrees with the empirical value used in the field equations of general relativity.

Lie symmetries and Financial Mathematics

Sophocleous, Christodoulos

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We consider a class of (1+2)-dimensional nonlinear partial differential equations. Special cases have been used to model recent problems in financial mathematics. Lie symmetries are used to construct two successive mappings that reduce the problems into problems with new governing equations being ordinary differential equations. Furthermore we show that these equations admit contact symmetries. The most significant is that they admit infinite-dimensional contact symmetries which is a hint for linearization. In fact, the Legendre transformation, which is a contact transformation, maps this class into a linear (1+2)-partial differential equation.

Around Landau levels, generalized theta functions and noncommutative tori

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In this talk I will report on joint research with Maximiliano Sandoval (PUC, Chile) ([Sandoval-Spera: arXiv: 2205.11235v1 [math.QA] 6th May 2022]), which can be viewed as a follow-up of my earlier investigations aimed at geometrically constructing representations of Riemann surface braid groups ([Spera: J. Geom. Phys. 94 (2015), 120–140]). The exposition, after providing appropriate mathematical and physical motivations and background, will focus on the well known relationship between theta functions and Heisenberg group actions. Specifically, we combine complex algebraic and noncommutative geometry in view of describing Hermitian-Einstein vector bundles on 2-tori via representations of noncommutative tori, thereby reconstructing Matsushima's setup ([Matsushima: Nagoya Math. J. 61 (1976), 161–195]) and making the ensuing Fourier-Mukai-Nahm (FMN) transform aspects transparent. We prove the existence of noncommutative torus actions on the space of smooth sections of Hermitian-Einstein vector bundles on 2-tori preserving the eigenspaces of a natural Laplace operator (a quantum harmonic oscillator). Motivated by the Coherent State Transform approach to theta functions devised in [Florentino-Mourão-Nunes: J. Funct. Anal. 192 (2002), 410–424], we extend the latter to vector valued thetas and develop an additional algebraic reinterpretation of Matsushima's theory making FMN-duality manifest again.

Survival probability and quantum transport in Grover walk on finite graphs

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We consider Grover walk on finite graphs with absorbing vertices (sinks). The evolution operator of the Grover walk often has localized eigenstates which do not cover entire graph. When such eigenstates are not supported on sinks, they become dark - they do not contribute to transport into sinks. Hence, the survival probability of the Grover walk can be non-vanishing. The dark space can be dived into three subspaces. For the first two, corresponding to the eigenvalues 1 and -1, we provide a recipe how to construct (non-orthogonal) bases using the concept of fundamental cycles. The last subspace can be determined from the random walk with the Dirichlet boundary conditions on the vertices connecting to the sinks. We illustrate the results on the example of the ladder graph, which shows a curious effect - the survival probability decreases with the length of the ladder, despite the fact that the number of dark states increases. The talk is based on results of collaboration with Jan Mareš, Jaroslav Novotný and Igor Jex from Czech Technical University in Prague, and Etsuo Segawa, Norio Konno and Shohei Koyama from Yokohama National University.

Optimal universal quantum circuits for unitary complex conjugation

Studziński, Michal

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Joint work with: Daniel Ebler, Michał Horodecki, Marcin Marciniak, Tomasz Młynik and Marco Túlio Quintino

Let U_d be a unitary operator representing an arbitrary d-dimensional unitary quantum operation. This work presents optimal quantum circuits for transforming a number k of calls of U_d into its complex conjugate $\overline{U_d}$. Our circuits admit a parallel implementation and are proven to be optimal for any k and d with an average fidelity of $\langle F\rangle = \frac{k+1}{d(d-k)}$. Optimality is shown for average fidelity, robustness to noise, and other standard figures of merit. This extends previous works which considered the scenario of a single call ($k = 1$) of the operation U_d, and the special case of $k = d - 1$ calls. We then show that our results encompass optimal transformations from k calls of U_d to $f(U_d)$ for any arbitrary homomorphism f from the group of d-dimensional unitary operators to itself, since complex conjugation is the only non-trivial automorphism on the group of unitary operators. In our work we extensively use tools coming from the representation theory, in particular the Schur-Weyl duality, and semidefinite programming.

A twisted Soul in a plain Body – a Cartan-Borel tale of the superstring

Suszek, Rafael R.

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The fundamental rôle of higher geometry – that of (n-)gerbes realising integral classes in the de Rham cohomology of manifolds and of the attendant higher categories – in the description of dynamics of (extended) distributions of charge and Maxwell-type gauge fields has, by now, been well established. In the talk, a generalisation shall be presented of Murray's formulation of HG to the $\mathbb{Z}/2\mathbb{Z}$-graded geometry with Lie-supergroup 'symmetries' – a natural setting of the Green–Schwarz super-σ-models with homogeneous spaces G/H of supersymmetry groups G as targets. The generalisation yields distinguished (n-)gerbe objects in the category of Lie supergroups, encoding the higher-categorial structure of the super-σ-models with defects and giving a simple picture of their κ-symmetry. We discuss a novel interpretation of these HG objects in the super-minkowskian setting $\mathrm{G}/\mathrm{H} = \mathrm{sISO}(d, 1|N)/\mathrm{Spin}(d, 1) = \mathrm{sMink}(d, 1|N)$ as resolutions of a nontrivial 'topology' behind the *supersymmetric* de Rham cohomology $H^\bullet(\mathrm{sMink}(d, 1|N))^{\mathrm{sMink}(d,1|N)}$ – that of the Soul of certain (non-Rothstein) Rabin–Crane super-orbifolds of $\mathrm{sMink}(d, 1|N)$, engendered by the action of the Kostelecký-Rabin discrete supersymmetry group Γ_{KR} on $\mathrm{sMink}(d, 1|N)$. The resolutions arise from an adaptation to the $\mathbb{Z}/2\mathbb{Z}$-graded setting of an HG extension of the Cartan-Borel homotopy quotient, obtained in collaboration with Gawędzki and Waldorf, and provides a definition of a (super-)σ-model on the super-orbifold $\mathrm{sMink}(d, 1|N)//\Gamma_{\mathrm{KR}}$ consistent with the worldsheet-orbifold construction worked out together with Runkel.

Geometrical structures of nested polyhedra

Szajewska, Marzena

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The polyhedra with exact reflection symmetry group G in the real 3D space is considered. Modifications of the shell of polyhedra that preserve the symmetry are described. The recursive rules for finding orbits with smaller radii, which provide the structures of nested polytopes, are demonstrated.

Homological Commutation Relation of Electric and Magnetic Fluxes

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The electric flux $\varPhi_{\mathrm{e}} = \int_{S_{\mathrm{e}}} D$ is defined by surface integral of electric flux density field D on a 2-chain S_{e} in the 3-dimensional space and the magnetic flux $\varPhi_{\mathrm{m}} = \int_{S_{\mathrm{m}}} B$ is defined by surface integral of magnetic flux density field B on another 2-chain S_{m}. For quantum-mechanical operators $\hat{\varPhi}_{\mathrm{e}}$ and $\hat{\varPhi}_{\mathrm{m}}$ representing the electric flux and the magnetic flux, we derive the canonical commutation relation $[\hat{\varPhi}_{\mathrm{e}}, \hat{\varPhi}_{\mathrm{m}}] = i\hbar n$ with a linking number n of ∂S_{e} and ∂S_{m} via quantization procedure of a constraint system. This relation is invariant under homological deformation of the 2-chains S_{e} and S_{m}. This result justifies quantization of an LC circuit and quantization of resonance cavity. We argue that an entanglement state of two cavities provides a platform for testing the so-called EPR paradox.

The n-bit parastatistics of $\mathbb{Z}_2^n$-graded (super)algebras

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In recent years Rittenberg-Wyler's $\mathbb{Z}_2^n$-graded "color" Lie (super)algebras received a renewed attention in connection to model building and physical applications. In this talk I survey a series of recent works focusing on the induction of n-bit parastatistics from $\mathbb{Z}_2^n$-gradings. I present how n-bit paraparticles can arise and be detected in multi-particle sectors of various quantum hamiltonians.

Off-Diagonal Long-Range Order in Low-Dimensional Quantum Systems

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A quantum system exhibits off-diagonal long-range order (ODLRO) when the largest eigenvalue of the one-body-density matrix scales as N, where N is the total number of particles. More generally, if the largest eigenvalue scales as N^C to define the scaling exponent C, then $C = 1$ corresponds to ODLRO and $C = 0$ to a single-particle occupation of the density matrix natural orbitals. When $0 < C < 1$, C can be used to quantify deviations from ODLRO. In this talk I start by discussing the behaviour of the exponent C in a variety of one-dimensional bosonic and anyonic quantum systems. I then pass to discuss $2D$ systems, comparing results for XY, Villain and interacting Bose gases. I finally consider the effect on ODLRO of long-range couplings.

Exact solutions to a family of nonlinear Schrödinger equations

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A wide variety of processes and phenomena studied in the theory of phase transitions, laser and plasma physics, quantum optics and many other branches of natural sciences are modelled on the ground of the so-called derivative nonlinear Schrödinger equations. In this talk, I will present exact solutions to a family of such equations derived as a generalization of the standard nonlinear Schrödinger equation extended by appending some linear and nonlinear terms to capture the interplay between dispersive and nonlinear effects. The foregoing exact solutions are presented in terms of Weierstrass and Jacobi elliptic functions and represent different kinds of solitary waves. These solutions are obtained using the method of differential constraints and Lie group analysis of the related system of evolution equations.

Higher category theory and n-groups as gauge symmetries for quantum gravity

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Higher category theory can be employed to generalize the notion of a gauge group to the notion of a gauge n-group. This novel algebraic structure is designed to generalize notions of connection, parallel transport and holonomy from curves to manifolds of dimension higher than one. Thus it generalizes the concept of gauge symmetry, giving rise to a topological action called nBF action, living on a corresponding n-principal bundle over a spacetime manifold. Similarly as for the Plebanski action, one can deform the topological nBF action by adding appropriate simplicity constraints, in order to describe the correct dynamics of both gravity and matter fields. Specifically, one can describe the whole Standard Model coupled to gravity as a constrained $3BF$ or $4BF$ action. The split of the full action into a topological sector and simplicity constraints sector is adapted to the spinfoam quantization technique, with the aim to construct a full model of quantum gravity with matter. In addition, the properties of the gauge n-group structure open up a possibility of a nontrivial unification of all fields. An n-group naturally contains additional novel gauge groups which specify the spectrum of matter fields present in the theory, just like the ordinary gauge group specifies the spectrum of gauge bosons in the Yang-Mills theory. The presence and the properties of these new gauge groups has the potential to explain fermion families, and other structure in the matter spectrum of the theory.

The Stinespring Form, Dynamical Semigroups, and Markovianity in Quantum Thermodynamics

vom Ende, Frederik

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Joint work with: E. Malvetti, G. Dirr, T. Schulte-Herbrüggen

We rigorously analyze the generators of quantum-dynamical semigroups of thermodynamic processes. More precisely, we characterize a wide class of GKSL-generators for quantum maps within thermal operations and argue that every infinitesimal generator of (a one-parameter semigroup of) Markovian thermal operations belongs to this class. Moreover, for the special case of a single qubit we even obtain a visualization of the "Markovian" subset of the thermal operations. The mathematical tools we use to tackle this problem are 1. the well-established field of Lie semigroup theory and 2. combining the environmental form of quantum channels (sometimes called Stinespring form) with the notion of dynamics. The latter results in a Taylor expansion of Stinespring curves which is in a one-to-one correspondence with the famous GKSL-generators.

Ultra-quantum coherent states

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A set of n coherent states is introduced in a quantum system with d-dimensional Hilbert space $H(d)$. It is shown that they resolve the identity, and also have a discrete isotropy property. There are two other important properties of these coherent states which make them 'ultra-quantum'. The first property is related to the Grothendieck formalism which studies the 'edge' of the Hilbert space and quantum formalisms. It shows that if a classical quadratic form $\mathfrak{C} < 1$, the corresponding quantum quadratic form $\mathfrak{Q}$ might take values greater than 1, up to the complex Grothendieck constant k_G. $\mathfrak{Q}$ related to these coherent states is shown to take values in the 'Grothendieck region' $(1, k_G)$, which is classically forbidden in the sense that $\mathfrak{C}$ does not take values in it. The second property shows that these coherent states violate logical Bell-like inequalities for a single quantum system, and in this sense they are deep into the quantum region. Three families of examples with $(d, n) = (3, 6)$, $(4, 8)$ and $(4, 12)$ are discussed.

Graded Jet Geometry

Vysoký, Jan

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The notion of jet bundles corresponding to vector bundles is an essential tool to understand the geometry of partial differential equations. On the other hand, graded manifolds form an interesting generalization of standard differential geometry with many applications in physics. It is thus only natural to try and look for a suitable jet geometry in the graded setting. Since graded manifolds are described solely by their sheaves of functions, this is a bit tricky. We start by a general graded vector bundle and show how one can define differential operators on its sheaf of sections. This can be used to define graded jet bundles. One must avoid traditional fiber-wise construction to do so. Instead, we show how everything can be done on the level of sheaves of its sections.

The noncommutative geometry of frame bundles

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Vector bundles in classical geometry typically arise as objects associated with something more profound, a principal bundle. In particular, each vector bundle E with fibre V is naturally associated with a principal $\mathrm{GL}(V)$-bundle, the so-called frame bundle of E. Frame bundles therefore constitute a key tool for studying vector bundles. Indeed, a connection on a frame bundle induces covariant derivatives on all associated vector bundles in a coherent way, leading to many important geometric constructions. This is the situation in Riemannian spin geometry where, for a spin manifold M, a "spin connection" on the frame bundle of M induces a covariant derivative on the spinor bundle, leading to the Dirac and Laplace operator on the spinor bundle. The noncommutative geometry of frame bundles, however, has not been studied conclusively, although the notion of a noncommutative principal bundle is certainly available. In this talk, which is based on https://arxiv.org/pdf/2304.14010.pdfarXiv:2304.14010, we present our approach to the subject.

Burge multipartitions and the AGT correspondence

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Joint work with: N. Macleod

Burge multipartitions are tuples of partitions that satisfy a cyclic embedding condition. When n-coloured, they generalise the "cylindric partitions" that provide a combinatorial model for integrable characters of the affine Lie algebra $\widehat{\mathfrak{sl}}(n)$ (moreover, they provide a crystal graph). When uncoloured, these m-tuples give a combinatorial model for characters of the W_m algebras (W_2 is the Virasoro algebra). Here, we show that the n-coloured Burge m-multipartitions yield the characters of the CFT cosets $\widehat{\mathfrak{gl}}(d)_m/\widehat{\mathfrak{gl}}(d-n)_m$ ($d \geq n > 0$, $m > 0$). Having previously shown that the same combinatorial objects give the $SU(m)$ instanton partition functions in $\mathcal{N} = 2$ supersymmetric gauge theory on $\mathbb{C}^2/\mathbb{Z}_n$, we have thus established a wide-ranging extension of the AGT correspondence.

Title Global View of Axion Stars

Wijewardhana, L. C. Rohana

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Ultra-light bosons make excellent candidates for dark matter. Axions, relaxions, and ultra light spin 1 Proca states are well-known examples. Such degrees of freedom can form gravitationally bound states known as boson stars during structure formation, and interactions (gravitational, self and mutual interactions) can modify the macroscopic properties of these objects. In this talk we review the recent efforts at studying these boson stars for defining parameters ranging from those related to QCD axions with particle masses of 10^{-5} electron volts to ultra-light axions with masses in the range of 10^{-22} electron volts. Ultra-light axions can form boson condensates the size of galactic centers while QCD axions can create condensates the size of asteroids. We explore how boson stars the size of entire galaxies can arise in multi component condensates that include several flavors of axions or multiple states of the same flavor. We explore their structural stability against collapse and possible decay due to particle number violating processes.

Variational cohomology and topological solitons in Yang-Mills-Chern-Simons theories

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In cohomological formulations of the calculus of variations obstructions to the existence of (global) solutions of the Euler-Lagrange equations can arise in principle. It seems, however, quite common to assume that such obstructions always vanish, at least in the cases of interest in theoretical physics. This is not so: for Yang-Mills-Chern-Simons theories in odd diemnsions > 5 we find a non trivial obstruction which leads to a quite strong non existence theorem for topological solitons/instantons. Applied to holographic QCD this reveals then a possible mathematical inconsistency. For solitons in the important Sakai-Sugimoto model this inconsistency takes the form that their U_1-component cannot decay sufficiently fast to extend to infinity like the SU_n-component.

The Landau Problem and non-Classicality in Symplectic Carroll Symmetry

Xavier Antunes Petronilo, Gustavo

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Joint work with: A. E Santana and S. C. Ulhoa

Carroll's group is shown as a group of transformations in a five-dimensional space ($\mathcal{C}$) obtained from the embedding of the Euclidean space into a (4,1)-de Sitter space. Three of the five dimensions of $\mathcal{C}$ are related to $\mathcal{R}^3$, and the other two to mass and time. A covariant formulation of Caroll's group is established in phase space. The Landau problem was studied. Finally, the negative parameter of the Wigner function is calculated.

The Rate of Dissipation of Topological Ideal Invariants in MHD

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The objective of the present presentation is to investigate the constancy of the topological invariants denoted non-barotropic generalized cross helicity and magnetic helicity in the case of non-ideal magnetohydrodynamic (MHD). In our previous works we considered only ideal barotropic and non-barotropic MHD. Here we consider dissipative processes in the form of thermal conduction, finite electrical conductivity and viscosity and the effect of these processes on the helicity conservation. Analytical approach has been adopted to obtain the mathematical expressions for the time derivative of helicity in a non-dimensional form showing the dependence of helicity dissipation on the Rayleigh and magnetic Rayleigh numbers. We also give a concrete model comparing the dissipation of magnetic and cross helicity and show that for small viscosity and heat conduction the rate of dissipation is comparable.

Localized Fermions on $\mathbb{C}\mathrm{P}^2$ Net-Zero Charged Topological Soliton

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Joint work with: Y. Amari and N. Sawado

The index theorem states that the number of fermionic zero energy modes corresponds to the topological charge Q of the background soliton. In this context, zero modes and localized modes are often identified. In other words, the number of localized modes that appear is typically equal to the topological charge. However, in situations where multiple solitons are mixed, this relationship is not trivial. We study Dirac fermions coupled with a

background field that is a topologically trivial soliton, which has a net topological charge $Q = 0$ but has a internal structure. As a tractable example, we employ an analytical soliton solution constructed by Din and Zakrzewski in the $\mathbb{C}\mathrm{P}^2$ nonlinear sigma model. This soliton is a mixture of instantons and anti-instantons. To clarify the relationship between the number of zero modes and the topological charge, we perform a spectral flow analysis using this configuration. This allows us to observe how zero modes manifest when $Q = 0$. In addition, by analyzing the wave functions of each mode, we can verify the occurrence of localized modes. Our results suggest the number of localized modes does not necessarily coincide with the number of zero modes and the topological charge.

Q-ball, Q-shell capacitor

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Joint work with: P. Klimas, L. C. Kubaski and N. Sawado

We study coupled (compact) Q-balls (-shells) in a $\mathbb{C}P^N$ nonlinear sigma model. Q-balls are stationary soliton solutions of certain complex scalar field theories with self-interactions. The $U(1)$ invariance of the scalar field leads to the conserved charge Q which is identified with the electric charge of the constituents for theories coupled to electromagnetic field. Compactons are field configurations that exist on finite size supports. The field takes its vacuum values outside this support. The compact nature of solutions permits the existence of novel harbor-type solutions having the form of Q-balls sheltered by Q-shells. In the case of gauged compact Q-balls (-shells), the electric charge can be strictly determined from the asymptotic behavior of the gauge field. We obtain the harbor solutions that the Q-ball is surrounded by the Q-shell with the net electric charge is zero.

Homotopy Manin triples and higher current algebras

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Manin triples of Lie algebras arise in many contexts. After recalling the general definition, I will recall one important class of examples involving current algebras, whose study leads naturally to the notions of vertex algebras and rational conformal blocks. Now, motivated by quantum Gaudin models and the geometric Langlands correspondence, one would like to generalize all this to complex dimensions higher than one. One approach to doing so starts with higher current algebras in the sense Faonte, Hennion and Kapranov. I will review the definition, which involves passing from Lie algebras to their differential graded (dg) analogs. In the dg setting, it is natural to relax the definition of a Manin triple, by requiring some statements to hold only up to homotopy. I will describe some explicit examples of such homotopy Manin triples, and describe some applications. This talk is based on recent work https://arxiv.org/abs/2208.06009 and work in progress, joint with Luigi Alfonsi.

Algebraic superintegrable systems from 2D conformal algebras

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Joint work with: Yao-Zhong Zhang and Ian Marquette

The construction of Hamiltonian superintegrable system based on Lie algebras and their universal enveloping algebras have been studied over last decades. However, most of those approaches rely on explicit differential operator realizations, homogeneous spaces and Marsden-Weinstein reduction. An alternative construction of the superintegrable systems in 2D Darboux spaces provided by Fordy and Huang showed that the polynomial algebras can be constructed using conformal symmetries. In this talk, we will then explain how this allow classification of commutants in the conformal algebra $\mathfrak{so}(3,1)$, and then provide algebraic Hamiltonians with integrals written in the algebraic forms i.e. in enveloping algebras of the generator of those underlying conformal algebras. Those will also display closure of their Berezin brackets and commutators without relying on explicit realization or representations, which allows to understand the construction of model on curved spaces such as Darboux spaces from a different and entirely algebraic perspective.

Instability and transition of pure states into mixed states: Quantum-statistical approach with non-Hermitian Hamiltonians

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It is known that quantum fluctuations can cause, under certain conditions, the dynamical instability of pure states that can result in their evolution into mixed states. We demonstrate that the degree and type of such an instability are controlled by the environment-induced anti-Hermitian parts of Hamiltonians. This is drastically different from the Hermitian case where the purity rate is identically zero, therefore, both the purity's value and pure states are strictly preserved during time evolution. Using the quantum-statistical approach for non-Hermitian Hamiltonians and related master equation, we derive the equations that are necessary to study the stability properties of any model described by a non-Hermitian Hamiltonian. It turns out that the instability of pure states is not explicitly seen in the evolution equation but can spontaneously occur in its solutions, for example due to quantum fluctuations. We argue that the density operator formalism with non-Hermitian Hamiltonians can be used to describe such phenomena, while the Schrödinger equation approach would have severe limitations in this regard.

Quasi-Hermitian quantum theory and zig-zag matrix algebras

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The real "zig-zag" matrices are introduced as a sparse-matrix subset of tridiagonal matrices T_{ij}, $i, j = 1, 2, \ldots$. They are characterized by the "zig-zag" vanishing of the off-diagonal elements, $T^{(ZZM)}_{2m-1,2m} = T^{(ZZM)}_{2m+1,2m} = 0$, $m = 1, 2, \ldots$. Their basic mathematical properties are outlined. Quantum mechanics of unitary systems using quasi-Hermitian Hamiltonians is recalled as a natural domain of their applicability.

Reduction cohomology of vertex algebras

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We study the algebraic conditions leading to the chain property of complexes for vertex operator algebra n-point functions (with their convergence assumed) with differential being defined through reduction formulas. The notion of the reduction cohomology of Riemann surfaces is introduced. Algebraic, geometrical, and cohomological meanings of reduction formulas is clarified. A counterpart of the Bott-Segal theorem for Riemann surfaces in terms of the reductions cohomology is proven. It is shown that the reduction cohomology is given by the cohomology of n-point connections over the vertex operator algebra bundle defined on a genus g Riemann surface $\Sigma^{(g)}$. The reduction cohomology for a vertex operator algebra with formal parameters identified with local coordinates around marked points on $\Sigma^{(g)}$ is found.