# A B S T R A C T S

# Plenary Sessions

## Modes for two-dimensional harmonic oscillators and their connection to ray optics

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The propagation of monochromatic laser beams that are highly collimated (paraxial) obeys equations that are mathematically analogous to the two-dimensional Schrdinger equation. In particular, the eigenstates of constant, linear, and quadratic potentials map onto laser beams with the interesting property that their transverse intensity profile is preserved under propagation up to a rigid transformation such as a scaling, a displacement, a rotation, or a combination of these. In this talk I discuss a ray-optical description of such beams, in particular a general family that includes the Hermite-, Laguerre-, and Ince-Gauss modes as special cases. This ray-optical description is equivalent to a classical description of the orbits in the potential, and employs several geometrical tools such as conformal maps, medial axes, and the Poincar sphere.

## Frobenius manifolds and Minimal string theory

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This talk is about of the computations of the correlation numbers in Minimal Liouville gravity.

We use the conjecture that the Douglas equation is applicable to the Minimal Liouville Gravity.

We found how to choose the desired solution of the Dougla equation and an appropriate form of the resonance transformation from the KdV times to the Liouville coupling constants to satisfy the needed constraints of MLG.

Using the connection of the String equation with the Frobenius manifold structure, we find the necessary solution of this equation.

This solution and the suitable choosen resonance transformation lead to the results which are consistent with the requirements of the models of MLG.

The solution of the Douglas equation has a very simple form in the flat coordinates on the Frobenious manifold.

## Picturing Quantum Processes.

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We present quantum theory and quantum computation entirely in terms of diagrams. An entire course on each of these subject can indeed be given in entirely diagrammatic terms, including, for example, parts of arguments that even in the usual textbooks are not treated formally. The conceptual underpinning is to take composition of systems as the primitive connective, having drawn lessons from some of the shortcomings of other axiomatic approaches for quantum theory. Our approach favours general processes over states, very much in line with the computer science tradition.

BC (2010) Quantum picturalism. arXiv:0908.1787 BC and A. Kissinger (fall 2015, 850 pp) Picturing Quantum Processes. Cambridge UP.

## Surprises in icosahedral symmetry.

Pierre-Philippe Dechant
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Icosahedral symmetry is the largest discrete symmetry in three-dimensional space, and thus many naturally occurring objects such as viruses, fullerenes and quasicrystals can display icosahedral symmetry. I will talk about the role of icosahedral symmetry and its generalisation Caspar-Klug theory in the structure of the protein capsids of viruses. The interplay between the protein capsid and the nucleic acid contained therein discovered recently has interesting implications for the assembly of viruses in terms of the RNA forming a Hamiltonian path between the icosahedral vertices of the protein capsid. I will discuss affine extensions of icosahedral symmetry, as well as their implications for virus structure and assembly. The same geometric principles appear to apply to fullerenes, in particular nested arrangements of icosahedral shells called carbon onions. The 3D polyhedral groups, in particular the icosahedral group, have also recently been shown to induce exceptional higher-dimensional root systems and symmetry groups, which I will briefly review.

## $SU(2|1)$ Supersymmetric Mechanics as a Deformation of $\mathcal{N}=4$ Mechanics

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We outline the recent progress in constructing deformed supersymmetric (quantum) mechanics models based on the world-line realizations of the semisimple supergroup $SU(2|1)$. Starting from the manifestly covariant $SU(2|1), d=1$ superspace approach, we present the models associated with the off-shell multiplets $(1,4,3)$, $(2,4,2)$ and $(4,4,0)$. Their peculiar superconformal subclass respects invariance under the extended conformal supergroup $D(2,1;\alpha)$. The $(4,4,0)$ models are naturally described in the framework of the $SU(2|1), d=1$ harmonic superspace. Like in the undeformed $\mathcal{N}=4$ supersymmetry, there exist two sorts of the multiplet $(4,4,0)$, the "ordinary" and "mirror" ones. As opposed to the undeformed case, the corresponding $SU(2|1)$ mechanics models are not equivalent to each other. We discuss their specific features.

## Discrete integrability: The octahedron relation, T-systems and pentagram maps

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The set of discrete integrable system in projective geometry, called the (higher) pentagram maps, is related to the octahedron relation or T-systems of type A in two ways. First, the lifting of the projective coordinates of the higher dimensional pentagram maps of Khesin and Soloviev, on which the discrete evolution acts, can be mapped to the solutions of the $A_d$ T-system, with wall boundary conditions which imply Zamolodchikov periodicity. Second, the evolution of the coordinates in the higher pentagram maps of Gekhtman, Shapiro, Tabachnikov and Vainshtein, generalizing the Schwartz map, is given by a cluster algebra mutation. This cluster algebra is described by the quiver of the octahedron relation (A-infinity T-system) wrapped on a torus with periods which depend on the map.

## Macroscopicity, localization and thermalization in the measurement space

Andrei Klimov

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We analyze the discrete phase-space representation for N-qubits and introduce a Q-function projected into the space of symmetric (invariant under particle permutations) measurements as a tool for studying the general properties many particle quantum systems in the macroscopic limit. A relation between the localization and Gaussianity of pure and mixed states is discussed in connection to the concept of quantum macroscopicity. The asymptotic evolution in the measurement space under action of random and chaotic Hamiltonians is analyzed in the framework of the thermodynamic approach. In particular, equilibration and thermalization in the space of symmetric measurements are discussed.

## Cubic interactions for higher spin gauge fields in flat and $AdS-5$

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In the first half of talk using Noether's procedure we present a complete solution for the trilinear interactions of arbitrary spins s1,s2,s3 in a flat background, and discuss the possibility to enlarge this construction to higher order interactions in the gauge field. Some classification theorems of the cubic (self)interaction with different numbers of derivatives and depending on relations between the spins are presented. Then in the second half a special embedding of the SU(4) algebra in SU(10), including both spin two and spin three symmetry generators, is constructed. A possible five dimensional action for massless spin two and three fields with cubic interaction is constructed. The connection with the previously investigated higher spin theories in AdS5 background is discussed.

## Population, relations and relevance of Vogel plane

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The universal Vogel's approach to theory of simple Lie algebras is presented. Particularly, universal expression for characters of adjoint representation of simple Lie algebras is presented and points with regular features of that characters are classified and shown to be completely described as solutions of certain Diophantine equations. Straight lines with populated points are noted, as well as universal relations between different populated points and lines. Applications in the theory and gauge fields and string are briefly listed.

## Phase Space and Symmetry Algebra of Extremal Black Holes

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We construct the classical phase space of geometries appearing in the near-horizon region of extremal black holes. This phase space consists of set of geometries diffeomorphic to each other which depend on a single periodic function. This set of metrics is equipped with a consistent symplectic structure which we use to define symplectic symmetries and their inifinite dimensional algebra. The symmetry algebra is a novel algebra which is an extension of the Virasoro algebra and admits a central charge. The central charge is the black hole entropy. We construct a representation of the symplectic charges in terms of a "generalized Liouville type stress-tensor" and outline the possible future directions.

## The elliptic modular double

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The elliptic modular double is an algebra formed from two Sklyanin algebras with the structure constants related by a modular transformation. It can be reduced to Faddeev's modular double for $U_q(sl_2)$ in a particular limit. Although this algebra was introduced in 2008, an integral operator, intertwining its equivalent representations, was considered already in 2003 for building an integral analogue of the Bailey chains techniques. Corresponding Bailey lemma yields a star-triangle relation which plays a key role in building the most complicated known solution of the Yang-Baxter equation in the form of an integral operator with an elliptic hypergeometric kernel. The elliptic modular double allows one to fix this solution uniquely. A finite-dimensional invariant null-space of the intertwining operator emerging for a particular two-index lattice of values of the spin is described by products of Jacobi theta functions with two different modular parameters. It yields new elliptic solutions of the Yang-Baxter equation through a reduction procedure.

## Connection matrices of boundary quantum Knizhnik-Zamolodchikov equations

Jasper Stokman
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Boundary quantum Knizhnik-Zamolodchikov (bqKZ) equations arise as consistency conditions for correlation functions of semi-infinite Heisenberg spin chains with reflecting boundary. The quantum symmetries of bqKZ equations are governed by boundary quantum groups or by the affine Hecke algebra of type C. I will explain the construction of a basis of solutions for an important class of bqKZ equations. I will relate the associated connection matrices to explicit elliptic solutions of the dynamical reflection equation.

# Parallel Sessions

## Imprecise probability for non-commuting observables

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It is known that non-commuting observables in quantum mechanics do not have joint probability. This statement refers to the precise (additive) probability model. I show that the joint distribution of any non-commuting pair of variables can be quantified via upper and lower probabilities, i.e. the joint probability is described by an interval instead of a number (imprecise probability). I propose transparent axioms from which the upper and lower probability operators follow. The imprecise probability depend on the non-commuting observables, is linear over the state (density matrix) and reverts to the usual expression for commuting observables.

## Nonlinear optical properties of gated graphene in the strong radiation field

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Graphene is a unique bridge between condensed matter physics and relativistic quantum field theory [1] and due to its extraordinary properties is of great interest for nonlinear optical applications [2]. Theoretical and experimental investigations on the nonlinear electromagnetic effects in graphene so far have been mainly focused on monolayer graphene. Meanwhile, there is growing interest in bilayer and trilayer graphene systems, where the electronic band structures are richer than in monolayer and can be easily manipulated by external fields. Theoretical and experimental studies [3, 4] have shown that a perpendicular electric field applied to bilayer of graphene modifies its band structure and may open an energy gap between the conduction and valence bands, which can be tuned between zero and midinfrared energies. The magnitude of the gap strongly depends on the number of graphene layers and its stacking order [4]. In the present work we develop a microscopic theory of a strong electromagnetic field interaction with multilayer graphene systems with an energy gap opened by external gates. We study the nonlinear response of bilayer and trilayer graphene, e.g Rabi oscillations corresponding to periodic creation and annihilation of particle-hole pairs, as a function of the gate voltage when one-photon interband excitation regime is induced by intense coherent radiation. We show that at resonant photon energy close to the energy gap and by adiabatically changing the gate potentials on time one can produce full inversion of the electron population between valence and conduction bands near the Lifshitz energy. The proposed method resembles well known Rapid Adiabatic Passage technique in quantum optics for population inversion in two level systems [5] (the population transfer in graphene systems can also be achieved by frequency chirped electromagnetic pulses). Due to relative flatness of the bottom (top) of conduction (valence) band in multilayer graphene systems in the presence of perpendicular electric field, the density of coherently created particle-hole pairs becomes quite large, which can make possible Bose-Einstein condensation of electron-hole pairs. We consider also excitonic states in graphene multilayers with opened energy gap. To take into account the Coulomb interaction, we use Hartree- Fock approximation that leads to closed set of equations for the single-particle density matrix.

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## Symmetries and substitutions in functional integrals

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Nonlinear nonlocal substitutions in functional integrals are shown to lead to the extension of functional spaces we integrate over. These new functional spaces may contain functions with singularities. In this way it is possible to formulate quantum theory in cases where singularities are essential, e.g. in quantum cosmology. The proper accounting of singularities in functional integrals gives an additional unexpected effect that we called "quantum restoration of broken symmetry".

## Automorphisms of the classical space groups

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The automorphisms of the classical space groups were important for relating crystal structures which differed in the labelling of cordinate axes or the choice of origin where equivalent choices could reasonably be made. Thus the choice of the origin as the site of a sodium atom rather than a chlorine atom in the rocksalt structure was purely at the whim of the author. The emergence of tables of (so-called) full-group irreducible representations of the classical three-dimensional crystallographic space groups has added a further important reason for the study of the automorphisms. The labelling of symmetry-determined properties by the labels of corresponding irreducible representations will depend on particular choices of the cordinate axes and the location of the origin. Some of the space groups exhibit quite interesting automorphisms which might be visualised as combinations of both translations and axial transformations. Examples will be provided of the physical interpretations of the different kinds of automorphisms including the less obvious kinds.

## The Coulomb problem in space with a compactified extra dimension and po- tential defined by Gauss' law

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We investigate the consequences of one extra spatial dimension for the stability and energy spectrum of the non-relativistic hydrogen atom with the potential defined by Gauss' law, *i.e.* proportional to $1/|x|^2$. The additional spatial dimension is considered to be either infinite or curled-up in a circle of radius $R$. In both cases, the energy spectrum is bounded from below for charges smaller than the same critical value and unbounded from below otherwise. As a consequence of compactification, negative energy eigenstates appear: if $R$ is smaller than a quarter of the Bohr radius, the corresponding Hamiltonian possesses an infinite number of bound states with minimal energy extending at least to the ground state of the hydrogen atom. We present numerical calculations of the energy spectrum by using Hamiltonian diagonalization techniques.

## Symmetry breaking of systems of ODEs with maximal symmetry and non-linear deformations

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For systems of ordinary differential equations (ODEs) possessing maximal symmetry $sl(n+2,R)$, the point symmetries are described generically in terms of a general solution to the system. For the corresponding Lagrangian of the system, the Noether symmetries are also described in terms of the general solution and their derivatives. The problem of deforming the system non-linearly by addition of "forcing" terms that preserve certain subalgebras of symmetries is considered, providing an alternative approach to the Ray-Reid systems.

## Symmetries of a pseudo-diffusion equation which describes a squeezing of coherent states

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We determine the nine infinitesimal symmetry generators $A_i$ of the *pseudo-diffusion equation* (PSD)

$$L\ Q \equiv \left[\frac{\partial}{\partial t} - \frac{1}{4}\left(\frac{\partial^2}{\partial x^2} - \frac{1}{t^2}\frac{\partial^2}{\partial p^2}\right)\right]\ Q(x,p,t) = 0\ ,$$

by two methods:

1. a pedestrian method, which I shall explain in details, and

2. the more sophisticated method which is due to Sophus Lie.

We identify the symmetry algebra $\mathbf{g}$ and prove that any function $b(t)$ in (PSD), other than the $t^2$ or a constant, reduces the symmetry algebra $\mathbf{g}$.

The above differential equation was originally derived to describe the behavior of the $Q(x,p;t \equiv e^{2y})$-function in the $(x,p)$-phase space as a function of a real squeeze parameter $y$. For this reason, I shall briefly review the *squeezed coherent states* $|x,p;y\rangle := D(x,p)S(y)|0\rangle$ and the *Husimi projection operator*, $|x,p;y\rangle\langle x,p;y|$.

I shall also discuss the group elements $G_i(\gamma) = \exp[\gamma A_i]$ and apply them to obtain complicated solutions from simple ones.

The linear operators $\{t^n L\}$ yield a realization of a Virasoro algebra without a central element, while $\{L, tL, t^2 L\}$ yield a realization of the subalgebra $so(1,1)$.

## Quantum Quench in AdS/CFT and Field Theory

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In recent years, holographic methods have thrown valuable light on universal scaling behavior in quantum quench involving critical points. In particular, holography has led to new scaling laws for fast but smooth quench. This talk will discuss these results and show that scaling in fast smooth quench is a universal feature of *all*quantum field theories irrespective of holography. We will also discuss how these results relate to those in sudden quench.

## Contractions from $osp(1|32) \oplus osp(1|32)$ to the $M$-theory superalgebra

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In this communication we study the generalized Weimar-Woods contractions of the superalgebra $osp(1|32) \oplus osp(1|32)$ in order to obtain an algebra that could be associated with the gauge group of $D = 11$ supergravity. We assume that the contracted algebras are fermionic extensions of the $M$- theory superalgebra.

We obtain only a superalgebra of this kind but it does not allows to trivialize the three-form of $D = 11$ supergravity. Thus, $D = 11$ supergravity cannot be related to a contraction of $osp(1|32) \oplus osp(1|32)$.

## Invariant Differential Operators for Non-Compact Lie Groups: an Overview

Vladimir Dobrev
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I review the progress of the project of classification and construction of invariant differential operators for non-compact semisimple Lie groups.Our starting points is the class of algebras, which we called earlier 'conformal Lie algebras' (CLA), which have very similar properties to the conformal algebras of Minkowski space-time, though our aim is to go beyond this class in a natural way. For this I us the new notion of parabolic relation between two non-compact semisimple Lie algebras.

## Texture zeros in neutrino mass matrix

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Standard Model does not explain neither quarks and leptons hierarchy problem nor their mixings. There are attempts to solve this issue through introducing additional so called "family" symmetries. Before discovery of nonzero lepton mixing angle 13 high hopes in explanation of the shape of mixing matrix were combined with non abelian symmetries. Nowadays, assuming one Higgs dublet, it is unlikely that this is still valid. Texture zeroes - which are combined with abelian symmetries are again intensively studied. Neutrino mass matrix is in natural way attractive to study them.

## A Dirac-Dunkl Equation on $S^2$ and the Bannai-Ito Algebra

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The Dirac-Dunkl operator on the 2-sphere associated to the $Z_2^3$ reflection group is considered. Its symmetries are found and are shown to generate the Bannai-Ito algebra. Representations of the Bannai-Ito algebra are constructed using ladder operators. Eigenfunctions of the spherical Dirac-Dunkl operator are obtained using a Cauchy-Kovalevskaia extension

theorem. These eigenfunctions, which correspond to Dunkl monogenics, are seen to support finite dimensional irreducible representations of the BannaiIto algebra.

## On the motion of classical three-body system with consideration of quantum fluctuations

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**Introduction.** As well-known the classical three-body problem is the system of the $8th$ order. We have proved that the general three-body problem may be formulated as the problem of geodesic flows on the $6D$ manifold; $M \cong \mathcal{M}_{\sqcup} \otimes \mathcal{S}^{\ni}$, where $\mathcal{M}_{\sqcup}$ denotes tangent bundle (the $3D$ hypersurface of an energy which is defined by diagonal matrix $g_{ij}(\{x\}) = (E - U(\{x\}))\delta_{ij}$ where $\{x\}$ the set of three coordinates, $E$ and $U(\{x\})$ respectively the total energy and interaction potential of the three-body system), $SO(3)$ is the space of the rotation group. This allows to find a new type symmetry and to implement more complete integration of system in result of which the initial problem is reduced to the system of the $6th$ order [1]. In the work is obtained the evolution equation describing of geodesic flow with consideration of quantum fluctuations. The last allows to develop high-performance algorithm for a numerical simulation of multichannel scattering in atomic-molecular collisions which takes into account the interactions between channels.

# References

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## Intrinsic symmetry groups

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There exists a special class of groups, called intrinsic groups which can be always constructed as the counterparts to the original (laboratory) symmetry groups and which actions commute to the laboratory groups. Maybe, they can be used to omit some restrictions due to no-go theorem in case of relativistic dynamis.

The purpose of the seminar is to show some properties of these intrinsic groups and their applications.

A good example is the rotation group $SO(3)$ in the three-dimensional space $R^3$ . The corresponding intrinsic group $\overline{SO(3)}$ has the same structure, though, in fact, it is anti-isomorphic to $SO(3)$. First of this group is generated by angular momenta operators in the laboratory frame, and the second one is generated by the angular momentum operators in the intrinsic (rotating with the quantum system) frame of reference. The non-trivial result is, that we get, in addition, not two but three independent quantum numbers $J$, $J_z$ and $J'_z$.

On the other hand, it turns out, that due to some constraints which have to be imposed onto the physical system described in terms of intrinsic degrees of freedom the corresponding intrinsic group is often restricted to its subgroup because a part of group operations breaks the required constraints.

It is obvious that the minimal intrinsic group which we can construct for a given physical system is the intrinsic group (or its subgroup) related to the symmetry group found in the laboratory frame. This hint allows to look for special symmetries which are not seen in the alboratory frame, especially so called partial symmetries.

## Oscillations of massive particles

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The quantum mechanical description of particle oscillations, the neutrinos for instance, has many drawbacks. Setting aside mathematical problems, this picture involves an artificial introduction of two bases: the physical basis of mass eigenstates, and the unphysical basis of 'interaction states', which raises questions about the interpretation.

In this work we propose a new description of this problem in the framework of quantum mechanics, in which the evolution of the system is solely characterized by the projection postulate. This framework allows to treat time as a 4th variable, and not merely an ordering parameter. We assume also, that the process of creation and detection, ie. interaction in general, of a particle occupies some volume in the space-time, which corresponds to the fact, that the particle mass is smeared in accordance to the uncertainty principle. This, in turn, triggers the possibility to detect a different mass state than it has been created. We show, that in our description the oscillations among mass eigenstates of particles are possible and arise rather naturally in certain conditions.

## Electroweak Model in the initial Universe

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The modern theory of electroweak processes is the Electroweak Model, which is in good agreement with experimental data, including the latest ones from LHC. This model is a gauge theory based on the gauge group $SU(2) \times U(1)$, which is the direct product of two simple groups. The operation of group contraction [1] transforms a simple or semisimple group to a nonsemisimple one. In particular the contracted special unitary group $SU(2)$ is isomorphic to

Euclid group $E(2)$. For better understanding of a complicated physical system it is useful to investigate its behavior for limiting values of its physical parameters.

In this talk we discuss the modified Electroweak Model with the contracted gauge group $SU(2;\epsilon)\times U(1)$ mostly at the level of classical gauge fields. It was shown [2]–[4] that at low energies the contraction parameter depends on the energy $s$ in the center-of-mass system, so the contracted gauge group corresponds to the zero energy limit of the Electroweak Model. Very weak neutrino-matter interactions and the linear dependence of their cross-section on neutrino energy are both explained from the first principles of the Electroweak Model as contraction of its gauge group. But for the same contraction of the gauge group there is another consistent rescaling of the representation space, which leads to the infinite energy limit of the Electroweak Model. Similar higher energies can exist in the early Universe.

The Electroweak Model goes in this limit through the five stages depending on the powers of the contraction parameters. At the infinite energy all particles lose mass, electroweak interactions become long-range and are mediated only by neutral currents. Very interesting is the Universe development and the limit Lagrangian $L_\infty$ can be considered as a good approximation near the Big Bang just as the nonrelativistic mechanics is a good approximation of the relativistic one at low velocities. Particularly we can conclude that the $u$-quark first restores its mass among other particles in the evolution of the Universe.

# References


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## Dunkl operator, integrability and pairwise scattering in rational Calogero model.


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The integrability of Calogero model can be expressed as zero curvature condition (commutativity of Dunkl operator). The corresponding to these flat connections non-local gauge transformation maps the Calogero wave functions to (symmetrized wave functions of the set of N free particles), i.e. relates corresponding scattering matrices. The integrability of Calogero model implies that any k-particles scattering is reduced to successive pairwise scatterings. The consistency condition of this requirement is expressed by analog of the Yang-Baxter relation.

## Quark-flavour Symmetries and their Violation in Quantum Chromodynamics

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In the Standard Model, heavy and light quarks reveal approximate flavour symmetries, triggering the formulation of powerful effective field theories based on quantum chromodynamics (QCD). Currently, the presicion tests of Standard Model in the rare weak decays of hadrons demand an accurate quantitative account of these symmetries and their violation effects in QCD and effective theories. I will discuss the current state of the art in solving this problem.

## Electromagnetic quantum effects in anti-de Sitter spacetime

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The two-point functions of the vector potential and of the field tensor for the electromagnetic field in background of anti-de Sitter (AdS) spacetime are evaluated. First we consider the two-point functions in the boundary-free geometry and then generalize the results in the presence of a reflecting boundary parallel to the AdS horizon. By using the expressions for the two-point functions of the field tensor, we investigate the vacuum expectation values of the electric field squared and of the energy-momentum tensor. Simple asymptotic expressions are provided near the AdS boundary and horizon.

## Energy flux constraints and Unitarity in CFT three point functions

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The positivity of the energy flux operator on CFT states other than the vacuum, has been successful in constraining the CFT central charges (i.e. the anomaly coefficients) in higher dimensions. Here we relate the constraints obtained from demanding the positivity of the energy flux to those obtained by imposing unitarity at a deep inelastic scattering experiment. This relation allows us to easily obtain constraints on the OPE coefficients of arbitrary operators.

## Kappa-deformed Covariant Quantum Phase Spaces as Hopf Algebroids

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We define general D=4 kappa-deformed phase space as given by Heisenberg double of kappa-deformed Poincare-hopf algebra. The standard kappa-deformed covariant quantum phase space with kappa-deformed Minkowski coordinates and commuting fourmomenta is obtained as the syubalgebra of such Heisenbeg double. Further we use the property that Heisenberg double defines quantum phase spaces with Hopf-algebroid structure. We describe this structure using purely algebraic method. The coalgebraic sector of bialgebroid is determined modulo the terms which define what we shall call the coproduct gauge freedom.

## Deformed oscillator algebra approach of Lissajous systems related to Jacobi EOP of type I and II

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We discuss how to extend the construction of 2D superintegrable Hamiltonians with separation of variables in spherical coordinates using combinations of shift, ladder, and also supercharge operators to models involving rational extensions of the two-parameter Lissajous systems on the sphere. These new families of superintegrable systems with integrals of arbitrary order are connected with Jacobi exceptional orthogonal polynomials (EOP) of type I (or II) and supersymmetric quantum mechanics (SUSYQM). Moreover, we discuss an algebraic derivation of the degenerate energy spectrum for the one- and two-parameter Lissajous systems and the rationally extended models. These results are based on finitely generated polynomial algebras, Casimir operators, realizations as deformed oscillator algebras and finite-dimensional unitary representations. Such results have only been established so far for 2D superintegrable systems separable in Cartesian coordinates, which are related to a class of polynomial algebras that display a simpler structure. We also point out how the structure function of these deformed oscillator algebras is directly related with the generalized Heisenberg algebras (GHA) spanned by the nonpolynomial integrals.

Talk based on arXiv:1503.03916

## Coherent states and physical vacua of solvable relativistic models

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Solvable models are simple two-dimensional field theories in which operator solutions of the field equations can be found in a closed and exact form. The corresponding Hamiltonians are non-diagonal in Fock (creation and annihilation) operators and hence the Fock vacuum is not their true ground state. We show with the example of the Thirring model, that the Hamiltonian can be diagonalized by a Bogoliubov transformation which generates the true lowest-energy eigenstate of the model's Hamiltonian. This vacuum state has a form of a coherent state quadratic in composite boson operators that are bilinear in the original (massless) fermion Fock operators, revealing in this way the four-fermion interaction structure of the model. The correlation functions have to be computed using this true ground state of the theory. For comparison, the light front version of the model is briefly discussed emphasizing the different status of the vacuum state in light front field theory.

## Non-Inertial Quantization: Reality or Fiction

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While the general relativity admits the space-times of increasing flexibility, the quantum theories are constructed by using always the same scheme of Hilbert spaces and their tensor products to represent the probabilities and correlations for microobjects as seen in the inertial frames in the Minkowski space-time. Yet, since several decades some exceptions from this picture are considered by describing the quantum theory as perceived from a uniformely rotating or uniformely accelerating reference frames. The uniformely accelerating one (Unruh) leads to still unfinished discussions, while the rotating case seems widely accepted. We are going to show, however, that even this last case presents a sequence of paradoxes which make the physical interpretation questionable. We are recently working to compare them with the assumed radiation in the accelerated frames (Unruh case).

## Localization and the Canonical Commutation Relations

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Let $R[x_1, x_2, ..., x_n; \partial_1, \partial_2, ...\partial_n]$ be the Weyl algebra of index $n$. It is well-known that $so(p, q)$ Lie algebras can be viewed as quadratic polynomial algebras in $R[x_1, x_2, ..., x_n; \partial_1, \partial_2, ...\partial_n]$ for $p + q = n$. What does not seem to be known is that the converse statement is also true, namely, that, by using extension and localization, we can construct homomorphisms of $R[x_1, x_2, ..., x_n; \partial_1, \partial_2, ...\partial_n]$ into certain localizations of the universal enveloping algebra, $U(so(p + 2, q))$, of $so(p + 2, q)$. We describe how these homomorphisms are constructed and using them we determine the necessary conditions that a $U(so(p + 2, q))$ module must satisfy in order to obtain representations of the appropriate Weyl algebra out of the considered $U(so(p + 2, q))$ module.

Specific and detailed results for low dimensional cases such as $so(2, 4)$, $so(4, 1)$ and $so(2, 1)$ are given. Important questions about physically appropriate symmetricity properties of the actions of the $x_i$ and $\partial_j$ in a given $U(so(p + 2, q))$ representation are also answered.

## Generalized Bloch states of a two-level atom in the field of counterpropagating waves: Application to the Kapitza-Dirac diffraction problem

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The Bloch-state approach to atomic translational states is extended out of adiabatic following and Raman-Nath approximations, while keeping the notion of potental energy for the initially populated internal state. The theory is applied to near-resonant Kapitza-Dirac diffraction of initial momentum state prepared as a Gaussian. Is confirmed ability of generation kinds of momentum distributions, promising for multipath atom interferometry.

## Superintegrability of Calogero-Coulomb problem and its Runge-Lenz vector

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We show that deformation N-dimensional (Euclidean, spherical and hyperbolic) Coulomb system by the potential of rational Calogero model preserves superintegrability property of initial system. We find explicit expression of the Runge-Lenz vector and symmetry algebra of rational Calogero-Coulomb problem, formulated in terms of Dunkl operators. This observation permits to claim that most of properties of Coulomb and oscillator systems can be lifted to their Calogero-extended analogs by the proper replacement of momenta by Dunkl momenta operators. Particularly, we show that N-dimensional Calogero-Coulomb system preserves integrability property in the presence of Stark term, and construct its complete set of constants of motion. We find, that in parabolic coordinates the systems admits complete separation of variables for N=2,3 and partial ones for N¿3. Finally, we show, that two-center Calodjero-Coulomb problem is also integrable system admitting, in elliptic coordinates, the complete separation of variables for N=2,3 and partial ones for N¿3.

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## Symmetries and quantization. Linearity and superintegrability

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We exemplify a quantization scheme that preserves the Noether symmetries of the underlying Lagrangian in order to construct the Schrdinger equation. Also, we show how superintegrable hamiltonian systems hide linearity, e.g., the TremblayTurbinerWinternitz system.

## Holographic topological entanglement entropy and ground state degeneracy

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Topological entanglement entropy, a measure of the long-ranged entanglement, is related to the degeneracy of the ground state on a higher genus surface. We construct a class of holographic models where such relation is similar to the one exhibited by Chern-Simons theory in a certain large N limit. Both the non-vanishing topological entanglement entropy and the ground state degeneracy in these holographic models are consequences of the topological Gauss-Bonnet term in the dual gravitational description.

## New solutions for physically consistent supergravity model-building

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New solutions of gravity mediated supergravity breaking are exhibited and a first step toward a complete classification is given.

## The discrete family symmetries as the possible solution to the flavor problem

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One of the most serious problems of the present-day elementary particle physics is the so-called flavor problem. The Standard Model explains neither particles masses nor the parameters appearing in the mixing matrix. Therefore, introduction of some extensions to the theory seems to be inevitable. Our approach consists of adding some new, discrete symmetry to those which have already existed in the SM (gauge symmetries). Since the possible explanation of the mixing matrixs parameters have been already widely studied within one Higgs doublet model, we have decided to extend also the scalar sector. Thus, the existence of the second Higgs doublet is allowed. These studies lead to some interesting conclusions.

## A Gigayear till the Day of Judgement

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A new class of analytical solutions the latent solutions has been obtained for a linear evolution second-order equation with constant coefficients in a 1+3 dimension with the help of symmetry operators. The existence of 18 arbitrary independent parameters in these solutions allows one, in particularly for the Schroedinger equation in a blank space, to put a question about the life-time of a wave packet. The structure of the latent solutions is that the time of spreading the wave packet can exceed any arbitrary large finite quantity.

## Self-similar analogues of Stark ladders: a path to fractal potentials

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We treat the eigenvalue problem posed by self-similar potentials, using discrete symmetry techniques. We find that the eigenfunctions of such problems are localized, even if the potential does not rise to infinity in every direction. It is shown that the logarithm of the energy displays levels contained in families; such families or classes are analogous to Stark ladders. Direct computation of matrix elements shows that the position of each ladder is determined by the specific details of the potential in a cell, but not by global transformation properties. The results are compared with numerical solutions of the Schr"odinger equation. Since our potentials are homogeneous functions under a particular affiffine transformation, they can be used to build fractals of many types.

## Aspects of the Liouville theory

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We review the Lagrangian of the Liouville theory with topological defects and present general solution of the corresponding defect equations of motion. We study the heavy and light semiclassical limits of the defect two-point function found via the bootstrap program. We show that the heavy asymptotic limit is given by the exponent of the Liouville action with defects evaluated on the solutions with two singular points. We demonstrate that the light asymptotic limit is given by the finite path integral over solutions of the defect equations of motion with the vanishing energy-momentum tensor.

## Electron gas in the ellipsoidal quantum dot: implementation of generalised Kohn theorem

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An electron gas in a strongly oblated ellipsoidal quantum dot with impenetrable walls in the presence of external magnetic field is considered. Influence of the walls of the quantum dot is assumed to be so strong in the direction of the minor axis (the OZ axis) that the Coulomb interaction between electrons in this direction can be neglected and considered as two-dimensional, coupled. On the basis of geometric adiabaticity we show that in the case of a few-particle gas a powerful repulsive potential of the quantum dot walls has a parabolic form and localizes the dot in the geometric center of the structure. Due to this fact, conditions occur to implement the generalized Kohn theorem for this system. The parabolic confinement potential depends on the geometry of the ellipsoid, which allows, together with the magnetic field to control resonance frequencies of transitions by changing the geometric dimensions of the QD.

## Quantum theory from a nonlinear perspective

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Quantum mechanics is, so far, the most successful theory scientifically as well as economically. Mathematically, it is linear, time-reversal and conservative. However, our everyday world is distinguished by a prevailing direction of time, dissipation of energy and phenomena (like the weather) that can rather be described in terms of nonlinear theories. How can these two views of the world be unified? Extending quantum mechanics simply by adding nonlinear terms apparently does not solve the problem. Therefore, in this talk, a different approach will be presented, namely, a nonlinear (but linearizable) reformulation of quantum mechanics that complements the linear version. The advantages over the linear formulation are a gain of information, a straightforward extension to open dissipative systems as well as formal compatibility with other fields of physics. This will be demonstrated with examples ranging from nonlinear dynamics and soliton theory through to BoseEinstein condensates and cosmology.

## The Quantum Measurement Model in the Phase-Space Representation

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In non-relativistic spinless quantum mechanics the quantization rules are in a one-to-one correspondence with the quantum distribution functions. The Weyl quantization rule corresponds to the Wigner quantum distribution function, which determines the expected values of the observed quantities of an isolated quantum object. The measurement procedure transforms an isolated (closed) quantum system in the open. The operators of observables of a rather simple explicit form converted to pseudo-differential operators of more complicated form. The measured values of these observables defined by the positive definite quantum distribution function, which is the convolution of the Wigner quantum distribution functions of a quantum object and quantum-measuring procedure. This quantum distribution function corresponds to an operational quantization rule that to classical observed from the class of tempered distributions assigns continuous linear pseudo-differential operators on rigged Hilbert spaces. These operators may regarded as perturbation of initial ones. Despite the perturbation of the spectral data, the structure of the spectrum of perturbed operator follows the structure of the spectrum of unperturbed operator. This fact makes possible the stable numerical description of the perturbed operator with eigenvectors of the unperturbed operator of an observable. The presence of the complete system of almost orthogonal (Sturmian) functions makes it possible to realize a stable numerical method for the study of the discrete spectrum of the measured observable of open quantum system.

## Introduction in AdS holography

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The lectures give a brief overview of the holographic approach to quantum critical phenomena. As a model example we discuss how to evaluate the usual conductivity and consider the phase transition between the normal and supercoducting phases. Then in the second lecture, we discuss solutions of the Einstein-Yang-Mills and Einstein-Yang-Mills Higgs SU(2) model in asymptotically AdS space and their associated hairy black hole AdS-Schwarzshield/AdS Reissner-Nordstrom solutions. Domains of existance of these solutions are investigated. Two types of finite energy, regular configurations are considered: magnetically charged solutions and monopole–anti-monopole pairs. The configurations are endowed with an electric charge and carry also a nonvanishing angular momentum density. Finally the holographic picture of the phase transition to the phase with broken symmetry is discussed.

## Lorentz invariance of spacetime intervals 'almost' implies EM and ED

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We show that beginning from the following simple assumptions, i) the speed of light is a universal constant, and ii) there are mutually interacting particles, with a linear 'source-field' relation, one at once arrives at electromagnetism (EM) and electrodynamics (ED) in all details. The conventional formulation of EM and ED relies on centuries long observations of Nature and careful laboratory measurements. The alternative we propose spares all those observational foundations, only to rein- troduce them as theoretically derived and empiricism-free consequences of the proposed formalism. There are merits to simplicity. For instance, when one learns that Poisson's equation emerges as a corollary of the theory, one immediately concludes that Coulomb's $1/r^2$ force is an exact law of Nature. Or, if it turns out that div.B$= 0$ follows from the theory, then non-existence of (at least classical) magnetic monopoles becomes a certainty. The list is longer than these two examples.

## Variational perturbation theory, nonperturbative calculations in QCD and beyond

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We present a nonperturbative method in QCD which is based on the variational perturbation theory (VPT) developed by A. N. Sissakian and I. L. Solovtsov. The structure of VPT series is different from the structure of the ordinary perturbative expansion. VPT, in the case of QCD, leads to a new small expansion parameter, $a$. This parameter obeys a special equation whose solutions are always smaller than unity for any value of the original coupling constant. In moving to low energy scales, where ordinary perturbation theory (PT) breaks down and direct perturbative calculations are not possible, the parameter $a$ remains small and we still stay within the region of applicability of the $a$-expansion method.

It is shown that within this method, which is complemented by the relativistic threshold factor, it is possible to obtain a good agreement between theoretical result and experimental data for various physical quantities (renormalization group invariant Adler functions, hadronic contributions t o anomalous magnetic moments of leptons and so on). We find out that the reason of a good consent is connected with quark-hadron duality.

As the PT cannot adequately describe quark-gluon systems at the low energy scale about 1 GeV and less, a method must be supplemented by nonperturbative formalism. To this end, one usually applies the operator product expansion (OPE), in which new parameters, vacuum condensates, are appeared. The Borel transform is the useful mathematical trick, which is used for QCD sum rule treatment. By using VPT, we construct a Borel representation of the Adler function and compare a result obtained with the OPE prediction and with an 'experimental' curve constructed from the $\tau$-data. We determine the residual condensates and show that within the method suggested the optimal values of these lower dimension condensates are close to zero.

## Multivariate Meixner Polynomials and a Discrete Model of the Two-dimensional Harmonic Oscillator with su(2) Symmetry

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A discrete model of the two-dimensional harmonic oscillator based on the two-variable Meixner polynomials is presented. It is shown that the system is superintegrable and has su(2) symmetry. The interpretation of the d-variable Meixner polynomials as matrix elements for SO(d,1) representations on oscillator states is reviewed.

## Quantum tunneling of a diatomic molecule through barriers

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A quantum transmission of barriers induced by metastable states in a quantum diffusion model of diatomic beryllium molecules on the surface copper is revealed. The calculation was performed for the beryllium molecule in an adiabatic approximation with the Morse potential. The parameters of the Gaussian potential barrier were selected from the experimental data on the quantum diffusion of hydrogen atoms on the surface of copper. It is shown that the quantum transmission of barriers increases the heat rate constants of quantum tunneling and lowers activation energy of the barrier for the composite molecular system at low temperatures.

## Hidden symmetries on toric Sasaki–Einstein spaces

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We describe the construction of Killing–Yano tensors on toric Sasaki–Einstein manifolds. We use the fact that the metric cones of these spaces are Calabi–Yau manifolds. The description of the Calabi–Yau manifolds, using toric data allows us to find explicitly the complex coordinates and write down the Killing–Yano tensors. As concrete examples we present the complete set of special Killing forms on the five-dimensional Sasaki–Einstein manifolds $T^{1,1}$ and $Y^{p,q}$. We construct the constants of motion for geodesics and prove the complete integrability.

# Poster Sessions

## Modeling of spin glasses from first principles of classical mechanics

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We have studied the classical $1D$ Heisenberg spin glasses from first principles of the classical mechanics. The system of recurrence equations are derived by minimization of the nearest-neighboring Hamiltonian in nodes of $1D$ lattice. It is shown that in each node of lattice, the solution of recurrence equations can bifurcate. Performing the consecutive node-by-node calculations, on *n-th* step instead of a single stable spin-chain we obtain a set of spin-chains which form Fibonacci subtree (graph). Theoretically is evaluated the computation complexity of an one graph $\propto 2^n K_s$, where $n$ and $K_s$ denote the subtree's height (the length of spin-chain) and Kolmogorov's complexity of a string (the branch of subtree) respectively. It is shown that the statistical ensemble may be represented as the set of random graphs. It is proved that all strings of the ensemble have same weights. This allows, in the limit of the statistical equilibrium with predetermined accuracy to reduce NP hard problem to the P problem. As shows comparing of statistical distributions of different parameters which are performed by using of NP and P algorithms, the coincidence of the corresponding curves is ideally. Based of this study we formulate a new representation for the partition function in the form of the one-dimensional integral on spin-chains energy distribution.

## Abelian 3d mirror symmetry on $RP^2 \times S^1$

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We consider a new 3d superconformal index defined as the path integral over $RP^2 \times S^1$, and get the generic formula for this index with arbitrary number of U(1) gauge symmetries via the localization technique. We find two consistent parity conditions for the vector multiplet, and name them P and C. We find an interesting phenomenon that two matter multiplets coupled to the CP-type vector multiplet merge together. By using this effect, we investigate the simplest version of 3d mirror symmetry on $RP^2 \times S^1$ and observe four types of coincidence between the SQED and the XYZ model. We find that merging two matters plays a important role for the agreement.

## Rectication of a Casimir Nanomachine with a Triangular Wave Signal

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We investigate a Casimir nano system composed of two thick dielectric disks separated by a thin gap. Initially the two disks have the same surface dielectric distributions. Two disks have quadratic dielectric regions. We use scattering approach in the weak coupling limit and show that the top plate experiences a torque $\tau(\Theta)$ if it rotates about its axes by an angle. Consequently, we will be able to calculate $\tau(\Theta) \propto sin(\Theta)$. We also study the dynamics of the system and find that the average angular velocity of the top disk is not zero.

## On the generalized minimal massive gravity

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In this paper we study the Generalized Minimal Massive Gravity (GMMG) in asymptotically $AdS_3$ background. The generalized minimal massive gravity theory is realized by adding the CS deformation term, the higher derivative deformation term, and an extra term to pure Einstein gravity with a negative cosmological constant. We study the linearized excitations around the $AdS_3$ background and find that at special point (tricritical) in parameter space the two massive graviton solutions become massless and they are replaced by two solutions with logarithmic and logarithmic-squared boundary behavior. So it is natural to proposed that GMMG model could also provide a holographic description for a $3-$rank Logarithmic Conformal Field Theory (LCFT). We calculate the energy of the linearized gravitons in $AdS_3$ background, and show that the theory is free of negative-energy bulk modes. Then we obtain the central charges of the CFT dual explicitly and show GMMG also avoids the aforementioned "bulk-boundary unitarity clash". After that we show that General Zwei-Dreibein Gravity (GZDG) model can reduce to GMMG model. Finally by a Hamiltonian analysis we show that the GMMG model has no Boulware-Deser ghosts and this model propagate only two physical modes.