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→ Book of Abstracts ←

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Conic Lagrangian surfaces and localized solutions of equations of relativistic gas dynamics

Anna Allilueva

(Moscow Institute of Physics and Technology, Russia)

Abstract: We study localized asymptotic solutions for linearized equations of realtivistic gas dynamics. We describe Lagrangian surfaces with conic singularities, corresponding to these solutions. We describa also geometric phase and discuss the possibility of exponential growth of small localized perturbations.

Some recent results on non self-adjoint Hamiltonians

Fabio Bagarello

(DEIM, Università di Palermo, Italy)

fabio.bagarello@unipa.it

Abstract: We discuss some recent results on quantum systems whose dynamics is driven by certain non self-adjoint Hamiltonians. In particular, we will describe a deformed version of the so-called generalized Heisenberg algebra and a no-go result for the damped quantum harmonic oscillator. We also will discuss some results on tridiagonal non self-adjoint factorizable Hamiltonians, and on their SUSY counterparts.

Time dependent propagator for an-harmonic oscillator with quartic potential.

Juraj Boháčik

(Institute of Physics, Slovak Academy of Sciences, Dúbravská cesta 9, 845 11 Bratislava, Slovakia.)

fyzibohj@gmail.com

Abstract: We define the propagator by the conditional path integral as

$$\mathcal{W} = \int \; [D\varphi(\tau)] \; \exp\left(-E[\varphi]\right), \tag{1}$$

where

$$E[\varphi] = \int_{0}^{\beta} d\tau \left[c(\tau)/2 \left(\frac{\partial \varphi(\tau)}{\partial \tau} \right)^2 + b(\tau)\varphi(\tau)^2 + a(\tau)\varphi(\tau)^4 \right], \tag{2}$$

and $c(\tau), b(\tau)$, and $a(\tau) > 0$ are functions of the time. We evaluate the integral $\mathcal{W}$ as the continuum limit of the finite dimensional integral derived from $\mathcal{W}$ and $E[\varphi]$ by time-slicing method. We show, that the an-harmonic pat of the propagator can be formally summed by the methods of the "umbral calculus". We find the operator function representing the infinite an-harmonic series.

In collaboration with P. Prešnajder and P. Augustín.

Self-adjoint extensions of the two-valley Dirac Operator with discontinuous infinite mass boundary conditions

Biagio Cassano

(Universita degli Studi di Bari, Italy)

biagio.gg.cassano@gmail.com

Abstract: We consider the four-component two-valley Dirac operator on a wedge in the plane with infinite mass boundary conditions, which enjoy a flip at the vertex. We show that it has deficiency indices (1, 1) and we parametrize all its self-adjoint extensions, relying on the fact that the underlying two-component Dirac operator is symmetric with deficiency indices (0, 1). The respective defect element is computed explicitly. We observe that there exists no self-adjoint extension, which can be decomposed into an orthogonal sum of two two-component operators: this effect is sometimes called "mixing the valleys. Joint work with Vladimir Lotoreichik.

Complex and non-local solitons, integrability and quantum systems

Francisco Correa

(Universidad Austral de Chile, Valdivia, Chile)

hipertuga@gmail.com

Abstract: The solitons represent one of the most beautiful bridges between mathematics and physics, finding applications in a wide range of phenomena in nature like water waves, nonlinear physics, optics, gravitation, among many others. In this talk, first we will introduce the concept of soliton and review some of their properties using as an example the most famous nonlinear integrable equation; the Korteweg de-Vries (KdV) equation. Next, the concept of parity and time reversal symmetry (PT-symmetry) is introduced in order to discuss PT-symmetric deformations of the KdV equation and new concept of complex multi-soliton solutions. We will also describe some non-local extensions of the Hirota and gauge equivalent non-local integrable equations.

Tachyon scalar field solutions in FRW space-time

Elif Ece Demir

elifece95@hotmail.com

Abstract: In this research, we studied tachyon one of the dark energy models in scalar field form for the flat FRW universe. We have obtained the exact solution of the field equations in Lyra geometry by using the deceleration parameter. Also, we have discussed the physical and geometrical quantities of tachyon one of the dark energy models.

The Splitting in the Bound State Energy for Some Singular Interactions Through a Perturbation Theory

Fatih Erman

(Izmir Institute of Technology, Turkey)

fatih.erman@gmail.com

Abstract: All the methods about the calculation of the splitting in the bound state energy of a double well potential due to the tunneling effect in quantum mechanics, are non-perturbative. In this talk, I will introduce a perturbative method to find the splitting in the bound state energy in a heuristic way for Dirac delta potentials. The formulation we introduce is rather general and includes various extensions of the potential, namely the Dirac delta potentials supported by curves and Dirac delta potentials supported by points on manifolds, and their relativistic versions.

This is a joint work with O. Teoman Turgut.

Quasi-Hermitian Random Matrices: Theory and Applications

Joshua Feinberg

(University of Haifa, Israel)

joshua@ph.technion.ac.il

Abstract: We discuss a model of random matrices H which are quasi-hermitian with respect to a fixed deterministic metric B. The metric maybe either taken to be fixed (deterministic) or random. For positive-definite metric B, the resulting spectrum of H is real, because H is similar to a hermitian matrix, whereas for indefinite metric B, the spectrum of H invades the complex plane, as pairs of complex-conjugate eigenvalues appear. (The latter case is analogous to the broken PT-symmetry phase.) In this talk we shall discuss the average spectra of such ensembles, for both types of metric. We will present analytical and numerical results for this spectrum in the complex plane in the large-N limit, and explain its behavior as the number of negative eigenvalues (a finite fraction of N) of the metric B increases.

Ladder operators for resonances and antibound states for hyperbolic Pöschl-Teller and hyperbolic step potentials.

Manuel Gadella

(Universidad de Valladolid, Spain)

manuelgadella1@gmail.com

Abstract: Ladder operators have been defined for numerous models with discrete spectrum. The question is now if ladder operators may be defined to connect state vectors for resonances (Gamow vectors) or between state vectors for antibound (virtual) states. We show that this is possible for two exactly solvable models. One is the hyperbolic Pöschl-Teller potential, which shows three different configurations with should be studied separately. One of these configurations, shows an infinite number of resonances. We construct two series of ladder operators connecting two series of Gamow states. Another configuration permits a similar construction including in the same series bound and antibound states, so that we may go from bound to antibound using ladder operators. The hyperbolic step potential shows antibound states only, which can be connected through ladder operators. This is a part of research in course.

Uwe Günther

(HZ Dresden-Rossendorf, Germany)

Abstract: t.b.a.

Graphene dots via discretizations of Weyl-orbit functions

Jiří Hrivnak

(Czech Technical University in Prague, Czech Republic)

jiri.hrivnak@gmail.com

Abstract: The application of two fundamental discretizations of Weyl-orbit functions to an electron propagation on the graphene triangular dots are presented. Symmetries of the point and labels sets inside dual weight and root lattices of root systems are provided by affine and extended affine Weyl groups. The discrete orthogonality relations of the Weyl-orbit functions over the dual weight and root point sets induce four types of complex discrete Fourier-Weyl transforms. Subtractively combining the transforms of the A_2 group induces two types of extended Weyl-orbit functions and their corresponding discrete transforms on the fragment of the honeycomb lattice. Special types of extended Weyl-orbit functions represent stationary states of the electron propagation on the triangular graphene dot with armchair boundaries. Further extension of the presented approach to the triangular graphene dots with zigzag boundaries is discussed. This is a joint work with Lenka Motlochová.

The hep-th zoo on Dirac materials

Alfredo Iorio

(Charles University, Czech Republic)

iorio@ipnp.troja.mff.cuni.cz

Abstract: In this overview I shall illustrate the work of our group on reproducing scenarios of high energy theoretical physics on Dirac materials, like graphene. The main goal will be to explain how versatile these systems are, and how far and wide into the hep-th territory we can explore with them.

I shall review why these materials lend themselves to the emergence of special relativistic-like matter and space. Then the focus will be on the emergence of curvature. I shall show why the low dimensions (2+1), and Weyl symmetry, are crucial to discover the specific arrangements that realize a Unruh-kind of phenomenon. I shall then point to a variety of other interesting scenarios, that include the BTZ black hole and de Sitter spacetime, and shall comment on how far we went in the direction of experiments.

The last part will be devoted to glimpses of as many fresh results as time will permit: from the time-loop to spot torsion, to the generalized uncertainty principle stemming from the underlying lattice length, from a model of grain-boundaries and their relation to (A)dS and Poincar spacetime algebras, to Unconventional Supersymmetry and the role of the two Dirac points of graphene.

Exact solutions of the sextic oscillator from the bi-confluent Heun equation

Artur Ishkhaynyan

(Institute for Physical Research, NAS of Armenia, Ashtarak, Armenia)

aishkhanyan@gmail.com

Abstract: The sextic oscillator is discussed as a potential obtained from the bi-confluent Heun equation after a suitable variable transformation. Following earlier results, the solutions of this differential equation are expressed as a series expansion of Hermite functions with shifted and scaled arguments. The expansion coefficients are obtained from a three-term recurrence relation. It is shown that this construction leads to the known quasi-exactly solvable (QES) form of the sextic oscillator when some parameters are chosen in a specific way. By forcing the termination of the recurrence relation, the Hermite functions turn into Hermite polynomials with shifted arguments, and, at the same time, a polynomial expression is obtained for one of the parameters, the roots of which supply the energy eigenvalues. With the $= 0$ choice the quartic potential term is canceled, leading to the reduced sextic oscillator. It was found that the expressions for the energy eigenvalues and the corresponding wave functions of this potential agree with those obtained from the QES formalism. Possible generalizations of the method are also presented.

On the Quantization of the Light-Front String Theory

Daya Shankar Kulshreshtha

(University of Delhi, India)

dskulsh@gmail.com

Abstract: In this talk i would discuss the quantization of the light-front string theory.

Charged Compact Boson Stars

Usha Kulshreshtha

(Delhi University, India)

ushakulsh@gmail.com

Abstract: I would consider charged compact boson stars in a theory of complex scalar field in the presence of an U(1) gauge field and gravity and discuss the results obtained for the 2D and 3D phase diagrams in the theory.

Spectral properties of the damped wave equation

Tereza Kurimaiová

(FJFI ČVUT, Czech Republic)

kurimter@fjfi.cvut.cz

Abstract: We provide numerous bounds for eigenvalues of the non-self-adjoint operator associated with the damped wave equation. Our approach is based on the Birman-Schwinger principle and Lieb-Thirring-type inequalities. This is joint work with David Krejcirik.

Choreography on Lemniscate: polynomial integrals of motion, superintegrability

Juan Carlos Lopez Vieyra

(Nuclear Science Institute, UNAM, Mexico)

vieyra@nucleares.unam.mx

Abstract: It will be presented that a 3 and 5 body choreography on algebraic Lemniscate by Bernoulli is superintegrable. All integrals are polynomial in coordinates and momenta. It is a joint work with Alexander Turbiner.

Superintegrability and separability in a magnetic field

Antonella Marchesiello

(Czech Technical University, Prague, Czech Republic)

marchant@fit.cvut.cz

Abstract: We study the problem of the classification of three dimensional superintegrable systems in a magnetic field in the case they admit integrals polynomial in the momenta, two of them in involution and at most of second order (besides the Hamiltonian). We start by considering second order integrable systems that would separate in subgroup-type coordinates in the limit when the magnetic field vanishes. We look for additional integrals which make these systems minimally or maximally superintegrable. Joint work with L. Šnobl.

Localization dynamics in multi-dimensional networks

Alexander Moroz

(Berlin, Germany)

wavescattering@yahoo.com

Abstract: The excitation dynamics in complex networks can describe the fundamental aspects of transport and localization across multiple fields of science, ranging from solid-state physics and photonics to biological signaling pathways and neuromorphic circuits [25]. While the effects of increasing network dimensionality are highly nontrivial, their implementation likewise becomes ever more challenging due to the exponentially growing numbers of sites and connections. To address these challenges, we formulate a universal approach for mapping arbitrary networks to equivalent one-dimensional lattices with strictly local inhomogeneous couplings, where the dynamics at the excited site is exactly replicated. We present direct experimental observations in judiciously designed planar photonic structures, showcasing non-monotonic excitation decays associated with up to 7-dimensional hypercubic lattices, and demonstrate a novel sharp localization transition specific to four and higher dimensions. The unprecedented capability of experimentally exploring multi-dimensional dynamics and harnessing their unique features in planar lattices can find multiple applications in diverse physical systems, including photonic integrated circuits.

In collaboration with Lukas J. Maczewsky, Kai Wang, Alexander A. Dovgiy, Andrey E. Miroshnichenko, Alexander Moroz, Max Ehrhardt, Matthias Heinrich, Demetrios N. Christodoulides, Alexander Szameit, and Andrey A. Sukhorukov.

Exactness of the Born Approximation and Broadband Unidirectional Invisibility

Ali Mostafazadeh

(Koç University, Istanbul, Turkey)

AMOSTAFAZADEH@ku.edu.tr

Abstract: Born approximation was proposed by Max Born in his monumental 1926 paper where he laid the foundations of quantum scattering theory. Because of its great theoretical and practical significance, this approximation scheme is covered in most standard textbooks on quantum mechanics. None of these, however, addresses the problem of finding potentials whose scattering problem is exactly solvable by the Born approximation. We give a simple condition under which a potential has this property in two dimensions. This condition identifies a very large class of potentials. This in turn allows us to solve another important open problem of scattering theory, namely constructing potentials that enjoy perfect (non-approximate) unidirectional invisibility in a finite spectral band of arbitrary width. Our analysis provides the first examples of quasi-exactly solvable scattering potentials, i.e., potentials whose scattering problem is exactly solvable for energies not exceeding a given value.

Effective impedance as a rational function

Anna Muranova

(Bielefeld University, Germany)

amuranova@math.uni-bielefeld.de

Abstract: It is known that electrical networks with resistors can be considered as weighted graphs. Similarly, the infinite electrical networks with resistors can be introduced. In this case the effective resistance of a network can be defined, and it is related to Laplace operator and random walk on graphs.

A natural generalization of a network with resistors is given by an electrical network with resistors, capacitors, and inductors (so called network with impedances). We define the mathematical notion of effective impedance of such finite networks and consider it as rational function of λ. Although initially $\lambda = i\omega$, where ω is the frequency of an alternating current, we consider more generally λ as taking arbitrary values in $\mathbb{C}$. We present some estimates of this function in terms of λ. Moreover, we discuss the possibility to define an effective impedance of a given infinite electrical network with impedances. The idea is to exhaust an infinite network by a sequence of finite networks. The main result is the following

Theorem 1 *Let $\{\mathcal{P}_n(\lambda)\}_{n=1}^{\infty}$ be a sequence of the effective impedances of the finite networks exhausting a given infinite network. Then the sequence $\{\mathcal{P}_n(\lambda)\}$ converges as $n \to \infty$ locally uniformly in the domain $\{\lambda \mid \operatorname{Re} \lambda > 0\}$.*

Therefore, the effective impedance of an infinite network can be defined in the right-half plane.

References

[1] Anna Muranova. *On the notion of effective impedance.* arXiv e-prints, page arXiv:1905.02047, May 2019.

[2] Anna Muranova. *Effective impedance over ordered fields.* arXiv e-prints, arXiv:1907.13239, July 2019.

On the estimates of the periodic eigenvalues for some special potentials

Cemile Nur

(Yalova University, Yalova, Turkey)

cnur@yalova.edu.tr

Abstract: We give estimates for the small eigenvalues of the non-self-adjoint Sturm-Liouville operators with periodic and antiperiodic boundary conditions for some special potentials including trigonometric polynomials. Moreover we provide error estimations and finally we present some numerical examples.

Potential Algebra Approach to Quantum Mechanics with Generalized Uncertainty Principle

Satoshi Ohya

(Nihon University, Japan)

satoshi.ohya@gmail.com

Abstract: Potential Algebra Approach to Quantum Mechanics with Generalized Uncertainty Principle Abstract: In this talk I shall study the potential algebra for several models arising out of quantum mechanics with generalized uncertainty principle. I shall first show that the eigenvalue equation corresponding to the momentum-space Hamiltonian

$$H = -(1+\beta p^2)\frac{d}{dp}(1+\beta p^2)\frac{d}{dp} + g(g-1)\beta^2 p^2 - g\beta,$$

which is associated with some one-dimensional models with minimal length uncertainty, can be solved by the unitary representations of the Lie algebra $su(2)$ if $g \in \{\frac{1}{2}, 1, \frac{3}{2}, 2, \cdots\}$. I shall then apply this result to spectral problems for the non-relativistic harmonic oscillator as well as the relativistic Dirac oscillator in the presence of a minimal length and show that these problems can be solved solely in terms of $su(2)$.

Some properties of real and complex eigenvalues of pseudo-Hermitian random matrices

Mauricio Pato

(Instituto de Física, Universidade de São Paulo)

mauriciopato70@gmail.com

Abstract: Pseudo-Hermitian are matrices which are connected to their adjoint by a similarity transformation

$$A^{\dagger} = \eta A \eta^{-1}$$

where η is a Hermitian matrix such that their eigenvalues are real or complex conjugate. Recently, it has been shown how matrices of random matrix theory (RMT) can be modified in order to satisfy the above condition. Moreover, the pseudo-Hermitian (pH) ensemble, contains a parameter such that by varying it, its eigenvalues undergo a transition from real to complex conjugate. In my talk, I will discuss the following results of the investigation of two aspects of this transition:

As the spectrum splits into separated sets of real and complex conjugate eigenvalues, those that stay on the real line show characteristics of an intermediate incomplete spectrum. On the other hand, the complex ones exhibit cubic repulsion for the class of real matrices and higher order repulsion for the complex and the quaternion matrices.

Treating the transition parameter as a time, it is shown how a system of differential equations can be derived to describe the motion of the eigenvalues as the transition proceeds. It is then shown that the eigenvalues can be interpreted as a system of vortices for which the exceptional points behave as saddle points.

Infrared fixed points in quantum conformal Weyl gravity

Leslaw Rachwal

(Czech Technical University, Prague, Czech Republic)

grzerach@gmail.com

Abstract: We compute functional one-loop RG flow in the quantum Weyl gravity. For this purpose, the algebraic expressions for partition function are studied on maximally symmetric and Einstein backgrounds. The threshold phenomena in IR are consistently included in this approach and the formalism of functional RG equation and analytic heat kernel methods is used. We show evidence for the existence of non-trivial FP in the IR limit of the RG flow and we also discuss its physical and mathematical properties.

Coherent states in Strained 2D Dirac materials

Alfredo Raya Montaño

(Universidad Michoacana, Morelia, Mexico)

drraya@gmail.com

Abstract: We construct the BarutGirardello coherent states for charge carriers in anisotropic 2D-Dirac materials immersed in a constant homogeneous magnetic field which is orthogonal to the sample surface. For that purpose, we solve the anisotropic Dirac equation and identify the appropriate arising and lowering operators. Working in a Landau-like gauge, we explicitly construct nonlinear coherent states as eigenstates of a generalized annihilation operator with complex eigenvalues which depends on an arbitrary function f of the number operator. In order to describe the anisotropy effects on these states, we obtain the Heisenberg uncertainty relation, the probability density, mean energy value and occupation number distribution for three different functions f . For the case in which the anisotropy is caused by uniaxial strain, we obtain that when the stress is applied along the x-axis of the material surface, the probability density for the nonlinear coherent states is smaller compared to when the material is stressed along the orthogonal axis.

Detection of gravitational waves via quantum effects

Yahia Saadi

(University of Batna, Algeria)

yahia.saadi@univ-batna.dz

Abstract: Since their direct detection in 2016, the study of gravitational waves and their interaction with matter become one of the most active lines of research on the theoretical and experimental levels. Although predicted since the early years of general relativity, the detection of gravitational waves was a very difficult task for many decades. One of the origins of this situation is the fact that the effect of a GW is only understood for systems made of at least two particles.

In this presentation, we will consider the interaction of a weak gravitational field with one particle (an electron for example).The importance of this problem comes from the fact that the electron can capture a geometrical Berrys phase during the passage of a gravitational wave. The latter can induce an electric current in a Hall quantum fluid by generating electromagnetic waves from which the possibility of converting a gravitational wave into an electromagnetic wave.

Lagrangian maniflods and quatization rules, corresponding to semi-classical eigenvalues of the Schroedinger equation on a surface with conic singularity

Andrei Shafarevich

(Moscow State University, Russia)

shafarev@yahoo.com

Abstract: We study semi-classical spectrum for the Scroedinger equation on a 2D surface with conic singularity. We obtain Lagrangian surfaces and quantization rules, corresponding to such eigenvalues. We sjow that the quantization rules are not standard; however, they have natural geomatric interpretation.

Superintegrability and time-dependent integrals

Libor Šnobl

(Czech Technical University in Prague, Czech Republic)

libor.snobl@fjfi.cvut.cz

Abstract: While looking for additional integrals of motion of several minimally superintegrable systems in static electric and magnetic fields, we have realized that in some cases Lie point symmetries of Euler-Lagrange equations imply existence of explicitly time-dependent integrals of motion through Noether's theorem. These integrals allow a completely algebraic determination of the trajectories (including their time dependence) although the systems don't exhibit maximal superintegrability in the usual sense.

Report on work in progress, based on bachelor thesis of Ondrej Kubu.

Spectral and scattering theory of one-dimensional coupled photonic crystals

Rafael Tiedra de Aldecoa

(Pontifical Catholic University of Chile)

rtiedra@mat.uc.cl

Abstract: We study the spectral and scattering theory of light transmission in a system consisting of two asymptotically periodic waveguides (one-dimensional photonic crystals) coupled by a junction. Using analyticity techniques and commutator methods in a two-Hilbert spaces setting, we determine the nature of spectrum and prove existence and completeness of the wave operators of the system.

Invariant solutions of reaction-diffusion equations on evolving domains

Michal Tichý

(FJFI ČVUT, Czech Republic)

michal.tichy@skaut.cz

Abstract: The reaction-diffusion problem on a growing domain cannot be solved analytically in general. However, the symmetries of the partial differential equations, which can be studied systematically, can be used to obtain certain types of analytic solutions, the so called invariant solutions. The invariant solutions can be used to gain some insight into large time behaviour of the solution and even to inspect instability.

Quantum many-body problem: (Lie)-algebraic aspects

Alexander Turbiner

(ICN-UNAM, Mexico)

a.turbiner@gmail.com

Abstract: Many body problem plays a central role in many physics sciences including celestial mechanics, atomic-molecular physics, nuclear physics. Its main characteristics is that the potential depends on relative distances between bodies alone. It is one of the most difficult problems in theoretical physics for more-then-two-body case. Recently, a new concept was pronounced: to study solutions of n-body problem which depend on relative distances ALONE. In such a case n-body problem becomes equivalent to either quantum top in constant magnetic field or to multi-dimensional particle moving in curved space with some remarkable cometric. Since the ground state function - the main object in quantum mechanics - and choreographies in classical mechanics are functions of relative distances ONLY they can be treated in much simpler way then up to now. Analogue of kinetic energy is (Lie)-algebraic operator which can be written in terms of $sl(\frac{n(n+1)}{2})$ algebra generators. n-body harmonic oscillator will be briefly discussed. Animations of choreographies in Newtonian gravity will be demonstrated.

One-Dimensional Spinless Salpeter Hamiltonian with Multiple Dirac Delta Potentials

Haydar Uncu

(Adnan Menderes University, Turkey)

uncuhay@gmail.com

Abstract: In this talk, we will presenti the one-dimensional semi-relativistic Schrödinger equation (also known as spinless Salpeter equation) for a particle interacting with finitely many Dirac delta potentials. We will first introduce the heat kernel techniques and then use it to establish a resolvent formula which includes all the information about the spectrum of the problem. We show that the ground state energy is bounded below and there exists a self-adjoint Hamiltonian associated with the resolvent formula. We show that there are at most N bound states and the ground state is non-degenerate. The scattering problem from N centers is analyzed by exactly solving Lippmann-Schwinger equation and the threshold anomaly has been observed for the two symmetrically located centers.

This is a joint work with Fatih Erman and Manuell Gadella.

$N = 2$ Supersymmetric Quantum Mechanics Algebra And Cosmic Strings

Özlem Yeşiltaş

(Gazi University, Turkey)

yesiltas@gazi.edu.tr

Abstract: Spinor Dirac particle in the presence of an external electromagnetic field in the cosmic string spacetime is studied . Within the cosmic string framework, a general Laplacian is constructed and the Dirac equation has been rewritten in the local coordinates. Then, the reduced Dirac equation is handled within the position dependent mass problem while more general potential families are obtained through the second order supersymmetric quantum mechanics.

Hiddenly Hermitian quantum models: The concept of perturbations

Miloslav Znojil

(NPI Řež, Czech Republic)

znojil@ujf.cas.cz

Abstract: In conventional Schrödinger representation the unitarity of the evolution of bound states is guaranteed by the Hermiticity of the Hamiltonian. A non-unitary isospectral simplification of the Hamiltonian, $\mathfrak{h} \to H = \Omega\,\mathfrak{h}\,\Omega \neq H^\dagger$ induces the change $\mathcal{L} \to \mathcal{K}$ of the Hilbert space of states, reflected by the loss of the Hermiticity of $H \neq H^\dagger$. In such a reformulation of the theory the introduction of an *ad hoc* inner-product metric reconverts $\mathcal{K}$ into the third, correct physical Hilbert space $\mathcal{H}$, unitarily equivalent to $\mathcal{L}$. The situation encountered, typically, in $\mathcal{PT}-$symmetric or relativistic quantum mechanics is shown more complicated after an inclusion of perturbations. The formulation and solution of the problem are presented. Some of the consequences relevant, e.g., in the analysis of stability are discussed.