CAMTP Symposium on Theoretical Physics

CAMTP - Center for Applied Mathematics and Theoretical Physics, University of Maribor Slovenia

www.camtp.uni-mb.si

Friday 19 April 2019

Mercure Maribor City Center Hotel

PROGRAM

FOREWORD

The seminars of CAMTP have a long tradition and history, since the foundation in 1990. In order to increase their visibility and scientific quality, and to maximize the audience, I decided to organize a one-day symposium rather than a series of many individual seminars. We shall have the opportunity to listen to 13 invited talks on many different topics in theoretical physics and applied mathematics, including the most recent advances in many different fields. The attendance is open for the public free of charge, including and especially for the students.

We shall also use this opportunity to celebrate the 60th birthday of Professor George Krylov (born 19 March 1959) of the Belarus State University in Minsk, who was our research collaborator at CAMTP for the period of two years 1997-1999. He also is very active in organizing annual international seminars on nonlinear dynamics in Minsk, since 1995, and plays a key operational role in running the international journal *Nonlinear Phenomena in Complex Systems*, which as electronic journal resides at the computer cluster of CAMTP, which is one of the journal's supporting institutions along with several major institutions in Minsk and in Saint Petersburg.

Finally, we shall enjoy the evening concert performed by Nejc Kamplet (born 1996 in Maribor) on piano, thus combining science and musical art, which is a long standing tradition of our plentiful Summer Schools, Christmas Symposia, Japan-Slovenia Seminars, European Advanced Studies Conferences and many other scientific conference events. Kamplet is internationally known pianist performing all over the world, including playing with big symphony orchestras.

Professor Marko Robnik, Director of CAMTP

Maribor, 4 April 2019

SCHEDULE OF TALKS

CHAIR	Robnik
09:00-09:45	Cvetič
09:45-10:30	Krylov
10:30-11:00	Prosen
11:00-11:30	Coffee and Tea
11:30-12:00	Biró
12:00-12:30	Žumer
12:30-13:00	Grushevskaya
13:00-13:30	Lozej
13:30-15:00	Lunch
CHAIR	Cvetič
15:00-15:30	Robnik
15:30-16:00	Perc
16:00-16:30	Prapotnik - Brdnik
16:30-17:00	Coffee and Tea
17:00-17:30	Romanovski
17:30-18:00	Petek
18:00-18:30	Ferčec
19:00-20:00	Concert Nejc Kamplet on Piano
20:00-23:00	Festive Dinner

Negative binomial coherent states

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Negative binomial coherent states are very special squeezed coherent states. They are important because being compatible with the distribution of the numbers of newly produced hadrons in high energy accelerator experiments, and there is hope to understand how such distributions may dynamically emerge based purely on quantum processes.

In this short talk I present theoretical speculations about possible constructions of Hamiltonians creating such a state, where the number of quanta follows a negative binomial distribution, from the Fock vacuum state. A unitary operator transforming a normed vector of the Hilbert state into another with the same norm can be constructed in general. This construction, however, is simple only in terms of fermionic operators, representing these two (initial and final) states as a spin half system.

On the other hand, in special cases, like the Glauber coherent state known from quantum optics, a shift operator, transforming the vacuum state into a Glauber state, is made of a simple Hamiltonian evolution operator, containing a dipole coupling to some external agent. We seek for an analogy of this for the negative binomial coherent states, and cannot find so far such a simple solution. The closest is a modified (squeezed) shift operator, where the Hamiltonian is not hermitic. We finally arrive at the perspective to consider a quantum noise temperature for negative binomial coherent states.

References

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Globally consistent three family standard models in F-theory

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We present recent developments in F-theory compactification, a strongly coupled regime of string theory. We focus on advances in constructions of globally consistent F-theory compactifications with continuous and discrete gauge symmetries and emphasize new insights into geometric classification of globally consistent three family Standard Models. We highlight the first example of the three family Standard Model with Z2 matter parity and a subsequent systematic exploration of the landscape of F-theory Standard Models.

References

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The qualitative properties of some dynamical systems

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We perform the qualitative study of some models represented by three-dimensional systems of ordinary differential equations. We propose an approach for determining the geometrical structure of the phase space and finding Hopf bifurcations in polynomial systems depending on many parameters - such systems are typical in biochemical network models - which combines some methods of qualitative analysis of autonomous systems of differential equations and effective methods and software tools of computational algebra. We use them to find invariant surfaces and parameter conditions under which Hopf bifurcations occur for the system in concern.

References

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Charge transport in topological materials: high energy $\vec{k} \cdot \vec{p}$ approximation

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Based on a self-consistent Dirac–Hartree–Fock field approach a quasi-relativistic model of graphene-like materials in the tight-binding approximation with accounting of relativistic electron terms $\pi(P_{3/2})$ and $\pi^*(D_{3/2})$ [1] have been used to elicit effects of nontrivial topology on charge transport. High-energy $\vec{k} \cdot \vec{p}$ Hamiltonian in this model describes a motion of Majorana-like superposition of charged model carriers [2,3]. Quantum statistical theory of non-abelian currents of Majorana-like superposition of charged carriers has been developed. Ohmic contribution to the current has been calculated as well as contributions stipulated by accounting of magnetoelectric effects (resulting in Hall current) and polarization ones (via Zitterbewegung effect and Klein tunneling).

References

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Topological properties of quasi-relativistic graphene model

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Within the framework of an earlier developed quasi-relativistic model of two-dimensional topological semimetals [1], that admits exotic non-abelian Majorana-like gapless fermion excitations [2,3], we investigate the structure of its quasi-momentum space. Some specific features of the model are demonstrated related to $N = 3$ flavours and gauge fields earlier introduced [4]. With the goal to extract peculiar topological characteristics of the model the non-abelian Zak phases [5] have been numerically calculated for several possible approximations including the simplest one corresponding to the known Wallace model of graphene (see e.g., in [6]). It has been demonstrated that the homotopy group of the model is $\mathbb{Z}_2 \times \mathbb{Z}_4$ that could be a result of the Majorana-like quasi-particle excitation presence.

References

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Structure, size and statistical properties of chaotic components in Hamiltonian systems with divided phase space

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Generic Hamiltonian dynamical systems are neither integrable nor fully chaotic. Whether the motion is chaotic or not depends on the initial condition. The phase space is divided into various invariant components. Typically, the chaotic component, known as the chaotic sea, surrounds an infinite number of Kolmogorov-Arnold-Moser (KAM) islands [1]. Invariant fractal sets known as cantori may also be present and limit transport in the phase space causing the phenomenon known as stickiness [2]. In the talk we will present the statistical properties of the largest chaotic component in a family of billiards introduced in [3] as well as the family of Lemon billiards [4]. By changing the value of the billiard parameters, we may acquire anything from a fully regular (integrable) to fully chaotic (ergodic) Hamiltonian systems. We divide the phase space into a grid of cells and determine which of them belong to the chaotic component by the iteration of a chaotic orbit. We compare the dynamics of the cell filling with the so-called random model [5, 6], that assumes completely uncorrelated cell visits and accurately describes the filling of cells for ergodic systems. We will show that due to stickiness the random model fails to describe the cell filling in systems where stickiness is present. The statistics of cell recurrence times provide a way of quantifying the stickiness of the structures in the phase space.

References

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Visual arts and physics: Entropy and complexity as common ground

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The 20th century is often referred to as the century of physics. From x-rays to the semiconductor industry, the human society today would indeed be very different were it not for the progress made in physics laboratories around the world [1,2]. What the past 100 years have been for science, the past millennium has been for the arts. From the late Byzantine and Islamic art to Renaissance, Realism and Pop art, the past 1000 years are packed with the most productive periods of our creative existence. The availability of digitized visual artworks allows us to perform large-scale quantitative analysis of the history of art. We have analyzed almost 140,000 visual artworks [3], the majority of which were paintings, by more than 2,300 artists created between the years 1031 and 2016. Based on the complexity and entropy of spatial patterns in the artworks, we were able to hierarchically categorize the artworks on a scale of order-disorder and simplicity-complexity, ultimately revealing a clear temporal evolution of the artworks that coincides with the main historical periods of art.

References

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Symmetries of quadratic systems of ODE's

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One of important problems arising in the investigation of the qualitative behavior of dynamical systems is determining whether a given system admits some kind of symmetry. In studies of dynamical systems described by autonomous polynomial systems of ordinary differential equations, we deal mainly with two kinds of symmetries: The rotational symmetry (Z_q-symmetry) and the time-reversible (involutive) symmetry. The existence of time-reversible symmetry in a polynomial system is related closely to the integrability of the system and, rotational symmetries have a connection to the second part of Hilbert's 16th problem.

For a given family of real planar polynomial systems of ordinary differential equations depending on parameters, we consider the problem of how to find the systems in the family which become symmetric after some affine transformation. We first propose a general computational approach for quadratic systems to solve this problem, and then demonstrate its usage for the case of the family of planar quadratic systems.

References

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Symmetries of quadratic systems of ODE's, *preprint*

Electrification of aircraft

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In a last couple of years, an electrification of land vehicles is developing very fast. Most car producers are already having one or more hybrid car models and/or car models that run solemnly on batteries. First hydrogen cars for a commercial use are also in a development. On the other hand, such progress is not seen in an aircraft industry. There are some electric and hybrid propulsion ultralight aircraft already available on the market. The first prototype ultralight passenger aircraft powered by a fuel cell was developed recently by German company DLR. Nevertheless, no larger aircrafts were yet developed. We would like to present benefits, limitations and challenges regarding the development of a small (19 and 70 seater) aircraft. Three types of aircraft will be discussed: hybrid aircraft (battery + inner combustion), battery driven aircraft and aircraft powered by fuel cells using hydrogen as a fuel. Above aircraft types will be shortly presented and compared with a conventional aircraft according to their technical and enviromental characteristics.

Many-body quantum chaos and random matrix theory

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One of the key goals of quantum chaos is to establish a clean relationship between the observed universal spectral fluctuations of simple quantum systems and random matrix theory. For single particle systems with fully chaotic classical counterparts, the problem has been essentially solved by M. V. Berry within the so-called diagonal approximation of semiclassical periodic-orbit sums.

In recent years, the questions of long-time dynamics at high energies, for which the full many-body energy spectrum becomes relevant, are coming at the forefront also for simple many-body quantum systems, such as locally interacting spin chains. Such systems seem to display two universal types of of behaviour which are nowadays usually termed as "many-body localized phase" and "ergodic phase". In the ergodic phase, the spectral fluctuations are typically excellently described by random matrix theory, despite simplicity of interactions and lack of any external source of disorder.

I will outline a heuristic derivation of random matrix spectral form factor for clean non-integrable spin chains [1], a prominent example of which is the Ising chain in a tilted (transverse + longitudinal) periodically kicking magnetic field. I will also present a specific model of the same type with nearest-neighbour interactions where random matrix spectral form factor can be rigorously proven. These models provide exactly solvable models of many-body quantum chaos [2,3], in a similar way as the Arnold's cat map or Baker map provide exactly solvable models of classical chaos.

References

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Parametric resonance in linear and nonlinear oscillators

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We study theoretically and computationally the behaviour of the classical and quantum parametrically periodically driven linear oscillator. As a basic paradigm of such a Floquet system we consider the case of the harmonic oscillation of the oscillator frequency, which is convenient to handle theoretically and computationally, while keeping the general features. We derive explicit analytic formula for the quantum propagator in terms of the classical propagator. Using this, we derive the explicit exact formula for the evolution of the expectation value of the energy starting from an arbitrary normalizable initial state. In the case of the starting pure stationary eigenstate the exponential evolution is exactly the same as for the classical microcanonical ensemble of initial conditions of the same starting energy. We confirm also numerically with absolute certainty that the borders of (in)stability regions classically and quantally coincide *exactly*, in accordance with the theory, and find a number of important empirical results, especially an equation of the elliptic type describing the rate of exponential energy growth inside the lacunae in terms of other system's quantities. We believe that our approach and findings are of generic linear type, i.e. applicable in most such linear Floquet systems, and present a strong motivation for a general theory, classically and quantally. Finally, we present some results on nonlinear Floquet oscillators, which are the subject of current research.

References

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Periodic solution and limit cycle bifurcations in some biochemical models

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We investigate the existence of first integrals and limit cycle bifurcations in three-dimensional systems connected to ecological and biochemical studies. We first present an approach to find invariant surfaces and Darboux integrals in polynomial systems, which can be used also to determine center manifolds of the system. Then, a new approach to investigate Andronov-Hopf and Bautin bifurcations on a center manifold is presented.

References

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Stabilization of skyrmion lattices in blue phases

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Cholesteric blue phases, as an example of anisotropic topological soft matter, are highly chiral nematic liquids that confined to thin layers exhibit numerous defect structures. Recently in a BP I confined to a very thin wedge cell few years ago predicted hexagonal 2D lattice of half-skyrmions was experimentally realized [1]. The lattice consists of nonsingular vertices - double twist cylinders characterized by 90 turns, which are separated by singular -1/2 disclination lines. Optical properties and modeled structures obtained with the minimization of the phenomenological q-tensor free energy expansion are used to explain observed microscope images and Kossel diagrams of half-skyrmion lattices [1-3]. In a cholesteric blue phase II sandwiched between two confining surfaces with specific periodic anchoring patterns, the formation of square and triangular quasi-two dimensional half-skyrmion lattices is demonstrated using the same numerical simulation approach [4]. Examples illustrate stabilizing and designing of complex birefringent profiles with potential for use in photonics.

References

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KONCERT

Nejc Kamplet, klavir

Petek, 19. april 2019, 19:00

Kavarna Art, Mercure Maribor City Center Hotel

PROGRAM

Peter Iljič Čajkovski: Tema in Variacije v F duru, op. 19, št. 6

Ludwig van Beethoven: Sonata št. 29 v B duru, op. 106 - "Hammerklavier"

I. Allegro
II. Scherzo: Assai vivace
III. Adagio sostenuto
IV. Introduzione: Largo...Allegro - Fuga: Allegro risoluto

CAMTP

CONCERT

Nejc Kamplet, piano

Friday, 19 April 2019, 19:00

Saloon Art, Mercure Maribor City Center Hotel

PROGRAM

Pyotr I. Tchaikovsky: Theme and Variations in F major Op. 19, No. 6

**Ludwig van Beethoven: Sonata in B-flat major, No. 29,
Op. 106, "Hammerklavier"**

I. Allegro
II. Scherzo: Assai vivace
III. Adagio sostenuto
IV. Introduzione: Largo...Allegro - Fuga: Allegro risoluto

SPEECH AT DINNER AND AFTER CONCERT
in Honour of George Krylov
by Marko Robnik
Hotel Mercure Maribor, 19 April 2019

Ladies and Gentlemen, Dear Colleagues and Friends, Dear George!

It is my great pleasure to have and to use this opportunity tonight to congratulate you, George, on your 60th birthday. We know each other since quite some time. More precisely, since February 1996 when I first visited Minsk, attending the conference Nonlinear Phenomena in Complex Systems, organized by Professor Viatcheslav Kuvshinov, who has kindly invited me to present a lecture. This was the first time that I met also other colleagues professors and researchers in physics in Minsk and in Belarus in general, and I was impressed by the quality of science, especially given the very difficult conditions under which colleagues in Belarus had to survive. It is that time that I have realized your personal very broad scientific interests, knowledge and activities in theoretical physics, also combined with computer science and computational physics. This surprise was even bigger, when I realized that you have also extremely large and heavy lecturing duties at your Belarusian State University in Minsk, at your Faculty of Physics. Your contributions to theoretical and mathematical physics are very significant, they have enriched your Faculty in Minsk, and contributed to the reputation of your family as physics-family. For those, who do not know George yet, I should mention that his wife Dr. Halina Grushevskaya Krylova is also a theoretical physicist, and she presented her nice talk today in the Symposium. In addition, their daugthers Ljuba and Nina both are also theoretical physicists, Nina even PhD, as well as Ljuba's husband Maxim, so one might speculate whether their son Alexander, grandson of George and Halina, has any chance to escape physics!

Based on, and due to your professional knowledge and experience in physics I have invited you to join CAMTP for some longer period, and it was my and our pleasure when you joined us for almost two years in the period 1997-1999. You have contributed significantly to the scientific output of the institute in the field of mathematical and theoretical physics. You also, together with Galina, joined us as invited speaker, at the 1st European Advanced Studies Conference in 2000, in Bexbach, Germany, which I have organized jointly with Dr. Andreas Ruffing, from the Technical University of Munich at the time.

Moreover, you have participated in our 4th Summer School and Conference Let's Face Chaos through Nonlinear Dynamics in summer 1999 with a very nice contribution, and again later, in the 8th Summer School in 2011 as an invited lecturer and speaker.

Next, I have to emphasize your indispensible important role in organizing the international Seminars Nonlinear Phenomena in Complex Systems, in Minsk, which is important for Belarus and for the broader international scientific area, especially for Eastern Europe. It is hard to imagine these annual meetings without your hard work. It was my great personal pleasure to repeatedly accept the kind invitations to participate in these meetings and to present most recent results.

Finally, I must emphasize your unique role in running and managing the international journal Nonlinear Phenomena in Complex Systems. It was an honour for me, to be involved in the foundation of the journal under the leadership of Professors Viatcheslav Kuvshinov and Viktor Gaysionok at the time, namely in 1998. In particular, it was my honour to publish there the first paper, whose citation is Vol. 1, No. 1, p. 1, 1998! I am glad that the journal is doing well over more than two decades, so far, which to a great extent is thanks to you personally!

Also, it was my pleasure in helping the journal by providing the CAMTP computer facilities for the online and electronic version of the journal. And, it must be emphasized, that you are the key person in running the online journal.

Therefore, George, we appreciate your great efforts in your scientific research, in lecturing physics and educating young students, promoting physics in its broadest sense, and for organizing scientific meetings and journals as very important activity for the further development of science not only in Belarus, but also internationally.

On this occasion, Dear George, I want to thank you for your work, and I wish you a very happy 60th birthday, many more happy returns, and lots of further success in science, for you personally and for your great physics family, also on behalf of the entire institute CAMTP!

Marko Robnik

Maribor, 19 April 2019