Frustracija v spin-1/2 verigah

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Raziskave kvantnega magnetizma so se izkazale kot izredno bogato področje za iskanje novih stanj snovi. Nizko-dimenzionalni sistemi še naprej ostajajo najpomembnejši modelni sistemi, kjer kvantne fluktuacije dominirajo pri nizkih temperaturah. Prehod iz paramagnetnega v feromagnetno ali pa antiferomagnetno stanje je eden najbolj standardnih primerov zloma simetrije v kondenzirani snovi. Pod značilno temperaturo, Curijevo v primeru feromagnetov in Néelovo v primeru antiferomagnetov, se magnetni momenti uredijo vzdolž določene kristalne smeri. V nekaterih primerih antiferomagnetov pa magnetni sistem paroma ne more minimalizirati vseh interakcij takrat govorimo o geometrijski frustraciji. Posledice geometrijske frustracije se odražajo v močnem znižanju Neelove temperature magnetnega urejanja in stanju z zapleteno magnetno ureditvijo ali pa celo s stanjem, kjer se magnetni momenti ne uredijo vse do temperature 0. V prispevku bom predstavil ključno vlogo magnetnih frustracij v spinskih verigah. V modelnem sistemu β-$TeVO_4$ smo tako odkrili pri različnih temperaturah in magnetnih poljih spinsko kiralno fazo, kolinearno fazo z valom spina, "spin-stripe" fazo ter nematično fazo [1-3].

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Frustration in spin-1/2 chains

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The field of quantum magnetism has proven to be a very rich playground to uncover novel states of matter. Low dimensional antiferromagnets remain model systems to stabilize ground states where quantum fluctuations dominate the low-temperature physics. In conventional antiferromagnets, magnetic moments align antiparallel with respect to the nearest neighbour moments below a characteristic Nel temperature. However, in certain low dimensional magnetic systems with geometrically frustrated lattice not all interactions can be pairwise optimised. In such cases, the role of geometrical frustration is typically manifested in a drastic suppression of Neel temperature, in a state with a very complicated non-collinear magnetic order or even in a complete suppression of long range magnetic order and establishment of elusive quantum spin liquid. In this talk I will demonstrate the crucial role of frustration on spin chains, which show remarkably rich phase diagrams as a function of temperature and magnetic field. On a archetypal example of β-$TeVO_4$, I will discuss vector chiral, collinear amplitude modulated, spin-stripe and nematic orders [1-3].

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Klasična in statistična termodinamika v energetiki od začetkov in pogled razvoja v prihodnost - od makro preko mikro do nano

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Termodinamika v energetiki se danes razvija na več znanstvenih področjih. Ena izmed pomembnejših področij je izračun termodinamičnih veličin stanja. Izračun termodinamičnih veličin stanja je možen s pomočjo klasične in statistične termodinamike. Klasična termodinamika izračunava termodinamične veličine brez vpogleda v mikrostrukturo materialov, v pomoč pa ji je eksperimentalna tehnika. Statistična termodinamika izračunava termodinamične veličine na osnovi molekularne strukture snovi. Predstavil bom uporabo termodinamike v energetiki in energetskih tehnologijah. Rezultati, pridobljeni z matematičnimi modeli, so podkrepljeni tudi z eksperimentalnimi rezultati in kažejo na zelo dobro ujemanje. Predstavil bom matematične modele v makro, mikro in nano področjih za primere, ki so zanimivi za energetiko.

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Classical and statistical thermodynamics from beginning and future development - from macro through micro to nano

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Nowadays, thermodynamics in energy engineering in many areas is present. One vital part is the calculation of thermodynamic properties. The calculation of the thermodynamic quantities of the state for real materials enables us both classical and statistical thermodynamics. Classical thermodynamics has no insight into the microstructure, but it allows the calculation of thermodynamical function of state with the help of macroscopic observation of phenomena. Unlike the classical thermodynamics the statistical thermodynamics does enable the computation of the thermodynamical functions of the state by studying molecular structure of the matter. All analytical data are compared with experimental results and they show good agreement. I will discuss the application of thermodynamics in energy engineering problems. I will show the mathematical models for macro, micro and nano regimes in some special applications related to energy technology.

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Exact Spectral Form Factor and Entanglement Spreading in a Minimal Model of Many-Body Quantum Chaos

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I show that the periodically driven Ising chain in transverse field, for some particular values of the couplings, can be regarded as a minimal model for many body quantum chaos. Specifically, I present an exact proof of the fact that the spectral correlations are described by random matrix theory. This result implies ergodicity for any finite amount of disorder in the longitudinal field, excluding the possibility of many-body localisation. The method used provides a novel route for obtaining exact non-perturbative results in non-integrable systems. As an example of this, I provide exact results on the entanglement spreading from a class of initial states.

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Maverick Temperatures

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A review of Stephen William Hawking's most physical ideas, in particular the Hawking radiation, the Hawking temperature and the Bekenstein–Hawking formula for the black hole horizon entropy is given. Recent thermodynamical reasoning about a stable equation of state, $S \sim E^a V^b$ including an invariant volume due to Christodoulou and Rovelli, is also peresented, solving the thermal stability problem (delivering positive heat capacity at fixed volume), and restoring Euler homogeneity ($a + b = 1$) at the same time. The value of the entropy associated to the horizon, however, deviates by a factor of $8/3$ from the original Bekenstein–Hawking formula in this framework.

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Večdelčna lokalizacija v sistemih koreliranih elektronov sklopljenih z različnimi bozonskimi prostostnimi stopnjami

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Sklopitev med elektroni ter spinskimi valovi vodi do delokalizacije v sistemu z neredom, ki ga elektroni čutijo preko naključno porazdeljenih potencialnih energij. Analiza temelji na analizi dinamike ene vrzeli v eno dimenzionalnem t-J modelu [1]. V primeru delokalizacije vrzeli je njena dinamika subdifuzivna.

Izračun dinamike ene vrzeli v primeru naključno porazdeljenih magnetnih polj pokaže da močan nered, ki se sklaplja na spinski podprostor, vodi do lokalizacije naboja ter tudi spinskih prostostnih stopenj. Z večanjem nereda se najprej lokalizirajo spinske prostostne stopnje. Do lokalizacije naboja pride šele pri večjih vrednostih nereda, ko spinska lokalizacijska dolžina pade pod velikost ene mrežne razdalje. Na koncu bom obravnaval tudi primer končnega dopiranja.

Obravnaval bo tudi primer, ko je kvantni delec v eni dimezniji ter naključnem potencialu sklopljen z disperzivnimi bozonskimi prostostnimi stopnjami. Bozonska disperzija je ključnega pomena za delokalizacijo delca [3,4].

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Many Body Localization in Correlated Electron Systems Coupled to Different Bosonic Degrees of Freedom

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I will show that electron-magnon interaction delocalizes the particle in a system with strong charge disorder. The analysis is based on results obtained for a single hole in the one–dimensional t-J model. Unless there exists a mechanism that localizes spin excitations, the charge carrier remains delocalized even for a very strong charge disorder and shows subdiffusive motion up to the longest accessible times [1].

When a single hole in a spin background is subject to a random magnetic field, strong disorder that couples only to the spin sector localizes both spin and charge degrees of freedom. Weaker disorder first causes localization in the spin sector. Carriers become localized for somewhat stronger disorder when the spin localization length is of the order of a single lattice spacing. I will also discuss finite doping [2].

Finally I will discuss the problem of a quantum particle in a random potential, coupled to different bosonic degrees of freedom [3,4]. Bosonic dispersion is responsible for the delocalization of the particle.

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Katastrofe v holesteričnih kapljicah

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Nedavno smo z razvojem naprednih eksperimentalnih metod za 3D konfokalno rekonstrukcijo direktorskega polja [1] prvič pokazali obstoj točkastih defektov višjega topološkega naboja -2 in -3 v holesteričnih kapljicah s pravokotnim površinskim sidranjem [2]. Površinsko sidranje v povezavi z nujnim pogojem sferične topologije ograditve povzroči frustracijo holesteričnega reda v kapljici in stabilizira netrivialna metastabilna stanja, sestavljena iz množice točkastih defektov, povezanih s kiralnimi mehurčki.

Tradicionalni model holesterikov s pomočjo Volterrove konstrukcije obravnava holesterik kot smektiku podobno strukturo s plastmi ničelne gaussove ukrivljenosti, ki ne dovoljuje obstoja točkastih defektov [3]. Za teoretično razlago opaženih struktur smo sestavili splošnejši model, v katerem holesterik predstavimo kot normirano Beltramijevo vektorsko polje, ki ga razvijemo v gradientno polje s kiralno perturbacijo [4]. Kiralni defekti različnih topoloških nabojev so manifestacije ničel harmoničnih funkcij, ki jih klasificiramo s pomočjo teorije katastrof [5]. Napovemo tudi potek razpada defektov, kar omogoči opis topoloških molekul in obnašanja holesteričnih defektnih linij, ki imajo vlogo topoloških vezi.

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Catastrophes in cholesteric droplets

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With the help of newly developed 3D confocal reconstruction method for director fields [1], we recently demonstrated the existence of defects with higher topological charges -2 and -3 in cholesteric droplets with perpendicular surface anchoring [2]. The anchoring, together with confinement with mandatory spherical symmetry, creates frustration of the cholesteric order in the droplet and stabilizes nontrivial metastable states composed of many point defects, bound by chiral bubbles.

Traditional cholesteric model, based on Volterra construction, treats cholesteris as smectic-like structure consisting of layers with zero Gaussian curvature, which does accomodate point defects [3]. On a quest to explain the experimental findings, we constructed a more general model of a cholesteric as a normalized Beltrami vector field, which can be expanded into a gradient field with a chiral perturbation [4]. Chiral defects of different topological charges are manifestations of zeros of harmonic functions, which can be classified with help of catastrophe theory [5]. We also predict unfoldings of defects, which allows us to describe topological moleculesand behaviour of cholesteric defect lines, which act as topological bonds.

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Martingale Strategy for Modeling Quantum Adiabatic Evolution

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The general goal of a quantum computers is to solve a discrete optimization problem which is a search for the ground state of a spin-glass like classical Ising model where the spin-spin couplings are not identical. This optimization is very common in mathematics, economics and engineering. When N denotes the total number of sites, the number of choices, 2^N, leads to an exponentially long solution time and nonlinear optimization problem. Quantum annealing is a procedure that reaches the ground state of a classical Ising model by turning off adiabatically the transverse magnetic field. This alternative quantum computation method solves the optimization problem for the classical Ising model faster if implemented on a quantum device.

We propose a strategy for modeling the behavior of an adiabatic quantum computer described by an Ising Hamiltonian with N sites and the coordination number Z, based on large coordination number expansion. In each order, the ground state energy is found neglecting the higher-order correlations between the sites, as long as the set of equations remains non-singular. The conditions of the appearance of a singularity, equivalent to the disappearance of energy gap in the given approximation, can be directly obtained from the equations. Then the next order in the expansion must be used, at the price of an N-fold increase in computational resources. This "martingale" strategy allows reducing the computational costs to a power of N rather than 2^N, with a finite probability of success.

The method which we used, is large coordination number expansion characterizing the general lattice Hamiltonian. It assumes that the coordination number Z (number of couplings of a given site with other sites) is large, so that next order corrective terms $1/Z^l$ give decreasingly smaller contributions to the lattice system dynamics. This expansion provides a general framework of hierarchical equations for n-sites reduced density matrices allowing us to determine systematically equilibrium properties such as the ground state as well as nonequilibrium dynamics.

Comparing the predictions to the experimental results obtained by using an adiabatic quantum computer would help quantify the importance of multi-site correlations, and the influence of decoherence, on its operation.

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GAIA - The 1 billion star surveyor

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In December 2013 the astrometric satellite GAIA was launched from the Kosmodrom Baikonur into an orbit around the Sun Earth Lagrange point L2 by the European Space Agency ESA. Equipped with two big mirrors of of 145cm x 50cm Gaia is an ambitious mission to chart a three-dimensional map of our Galaxy revealing the formation, composition and also evolution of our Galaxy. Gaia will provide positional and radial velocity measurements with very high accuracies which are needed to have a stereoscopic and kinematic census of about one billion stars which amounts to about 1 per cent of the Galactic stellar population. Besides the precise determination of the positions in the sky and the proper motions of stars its equipment allows photometric and spectroscopic measurements which will lead to new and precise results for different fields in astronomy e.g. like precise radii of planet-hosting Keplerstars and consequently better determinations of the radii of the planets in these extrasolar systems.

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Topological shapes of electric double layers

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Charged surfaces in contact with liquids containing ions are accompanied in equilibrium by an electric double layer consisting of a layer of electric charge on the surface that is screened by a diffuse ion cloud in the bulk fluid. This screening cloud determines not only the interactions between charged colloidal particles or polyelectrolytes and their self-assembly into ordered structures [1], but it is also pivotal in understanding, for example, how the interaction of a charged colloidal particle with an oil-water interface can be tuned from attractive to repulsive by varying the salt concentration [2]. However, little is known to what spatial complexity the electric double layers can be designed. Here, we show that electric double layers of non-trivial topology -including tori, multi-tori and knots- can be realised in charged colloids with complex-shaped particles, using numerical modelling. We show that the topology of double layers can be defined via a cut-off in the ion concentration without any loss of generality, and demonstrate that the double layer topology can be tuned by changing the Debye screening length of the medium, or by changing the shape and topology of the (colloidal) particle [3]. More generally, this work is an attempt to introduce concepts of topology in the field of charged colloids, which could lead to novel exciting material design paradigms. If time permits, we will finally discuss the coupling of electric double layers to a nematic texture, as dictated by a liquid crystalline medium.

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Kršitev univerzalonsti leptonskega števila

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Mnoge študije fizike izven Standardnega modela so spodbudile uganki opaženi v razpadih mezonov B. Obstajata uganki $R_{D^{(*)}}$ and $R_{K^{(*)}}$. Prva je opažena pri razpadih, katere provzroči nabiti tok v razmerju razpadnih širin za $B \to D^{(*)}\tau\nu$ in $B \to D^{(*)}\mu\nu$ in drugo uganko določi razmerje med razpadnimi širinama za $B \to K^{(*)}\mu^+\mu^-$ and $B \to K^{(*)}e^+e^-$. Izmerjena vrednost in vrednost izračunana s pomočjo pripspevkov Stnadardnega modela za anomalni magnetni moment muona se neujemata. Vse te anomalije kažejo na morebitno kršitev univerzalnosti leptonskega 'števila. Praviloma se za opise $R_{D^{(*)}}$ and $R_{K^{(*)}}$ uporabljajo metode efektivnih Lagrangianov. Modeli Nove fizike, ki vsebujejo lahke leptokvarke lahko razložijo B mezonske anomalije. V primeru, da je Nova fizika prisotna v razpadih mezonov B, obstajajo procesi na nizkih in visokih energijah kateri lahko dodatno testirajo prisotnost Nove fizike.

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Lepton flavour universality violation

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Currently B meson puzzles motivate many studies of New Physics due to the observed deviations from the Standard Model predictions. There are two B meson puzzles $R_{D^{(*)}}$ and $R_{K^{(*)}}$. The first one denotes the deviations in the decays driven by the charge current in the ratio of the decay widths for $B \to D^{(*)}\tau\nu$ and $B \to D^{(*)}\mu\nu$, while the second one is related to the ratio of the decay widths for $B \to K^{(*)}\mu^+\mu^-$ and $B \to K^{(*)}e^+e^-$. Also, the measured muon anomalous magnetic moment differs from the SM predictions. All these anomalies points towards Lepton number universality violation. Usually, the effective Lagrangian approach containing New Physics are used to approach $R_{D^{(*)}}$ and $R_{K^{(*)}}$. Among many models of new Physics, varieties of leptoquark models are suggested to resolve both B meson anomalies. If New Physics is confirmed in B decays a number of processes at low and high energies should confirm its presence.

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Dinamika nekaterih analitičnih (iterativnih) preslikav

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Predstavila bom problem centra in pristop za določitev cikličnosti centrov v preslikavah, podanih z

$$f(x) = -x - \sum_{k=1}^{\infty} a_k x^{k+1}. \qquad (1)$$

Glavna motivacija za zgoraj omenjena problema izhaja iz študije problema centra in problema cikličnosti ravninskih sistemov NDE. Prav tako bom obravnavala bifurkacije limitnih ciklov vsake komponente raznoterosti centra nekaterih posebnih primerov preslikav (1), ki izhajajo iz algebraičnih enačb oblike $x + y + h.o.t. = 0$.

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The dynamics of some analytic (iterated) maps

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I shall discuss the center problem and the approach to estimate the cyclicity of centers in maps given by

$$f(x) = -x - \sum_{k=1}^{\infty} a_k x^{k+1}. \tag{1}$$

The main motivation for these problems originates from the study of center and cyclicity problems of planar systems of ODEs. I will also consider the bifurcation of limit cycles from each component of the center variety of some particular cases of maps (1) arising from algebraic equations of the form $x + y + h.o.t. = 0$.

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Fizika slovenskih leposlovnih del: s teorijo kompleksnih mrež do novih spoznanj

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V prispevku bomo pokazali, kako lahko orodja s področja znanosti o kompleksnih sistemih uporabimo za vrednotenje nekaterih statističnih lastnosti pisnih besedil. Naša študija sestoji iz dveh delov. V prvem delu se osredotočimo na osnovne statistične lastnosti besedil in na porazdelitev pogostosti besed. Izkaže se, da pojavnost besed glede na njihov rank približno sledi potenčni funkciji, kar je v skladu z Zipfovim zakonom [1]. Naši rezultati kažejo na to, da se z naraščajočo priporočeno starostjo bralcev tako dolžina besedil kakor tudi povprečna dolžina besed monotono povečujeta. Po drugi strani pa se delež unikatnih besed in vrednost Zipfovega eksponenta zmanjšujeta [2]. V drugem delu naše študije uporabimo orodja s področja teorije kompleksnih mrež za opis strukture besedila in za vrednotenje interakcij med literarnimi liki [3]. Naši rezultati pokažejo, da sintaktična povezanost besed tvori kompleksno in heterogeno mrežo, ki izkazuje lastnosti mrež malega sveta. Prav tako se izkaže, da so mreže besed manj modularne in bolj učinkovite pri besedilih namenjenim starejšim bralcem. Nekoliko pričakovano pa narava socialnih interakcij med literarnimi liki z naraščajočo starostjo bralcev postaja vse bolj kompleksna [2]. V študiji izpostavimo, da tovrstni empirični pristopi, ki temeljijo na znanosti kompleksnih sistemov, predstavljajo pomembno vlogo na področju sodobne kvantitativne lingvistike in imajo velik potencial v kontekstu razvoja avtomatizirane klasifikacije literarnih del.

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Physics of Slovene belles-lettres: insights from complex network approaches

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In the present contribution we demonstrate how the tools from the realms of complexity science can be used to quantify some statistical properties of written language. Our study consists of two parts. In the first part we focus on basic statistical properties of texts and on the frequency-rank distribution of words. We show that the frequency of word occurrence is roughly an inverse power-law function of its rank, which is in accordance with the Zipf's law [1]. Our results indicate that with the increasing recommended age of readers, the length of texts and the average length of words increase, whereas the fraction of unique words and the Zipf's exponent decrease [2]. In the second part we utilize the complex network theory to describe the structure of language as well as the interactions between characters [3]. Our findings reveal that the syntactic connectivity of words forms a complex and heterogeneous network that is characterized by small-world properties. Moreover, it turns out that the extracted networks of words from texts for older age groups are less modular and more efficient, whereas the social interactions between literary characters become progressively more complex with increasing recommended age for readers [2]. Taken together, we demonstrate that such empirical complexity science-based approaches can be a valuable repertoire in the field of modern contemporary linguistics and have a huge potential in the development of automated classifications of literary works.

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Časovno odvisen matrično produktni nastavek za interagirajočo reverzibilno dinamiko

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Predstavila bom eksplicitni časovno odvisni matrično produktni nastavek, ki opiše časovno evolucijo poljubne lokalne opazljivke v interagirajočem in deterministčnem diskretnem modelu, ki so ga vpeljali Bobenko in sodelavci [1]. Konstrukcija nastavka vsebuje eksplicitno rešitev problema inverznega sipanja v realnem prostoru in času. Uporabnost nastavka bom prikazala na dveh primerih; eksaktnem izračunu dinamičnega strukturnega faktorja in profilu magnetizacije po časovni evoluciji ekstremnega primera nehomogenega začetnega stanja. Oba rezultata rigorozno demonstrirata balističen transport z difuzijskimi popravki.

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Time-dependent matrix product ansatz for interacting reversible dynamics

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I will present an explicit time-dependent matrix product ansatz (tMPA) which describes the time-evolution of any local observable in an interacting and deterministic lattice gas, specifically for the rule 54 reversible cellular automaton of Bobenko *et al* [1]. The construction is based on an explicit solution of real-space real-time inverse scattering problem. I will discuss two applications of this tMPA; the exact and explicit computation of the dynamic structure factor, and the solution of the extremal case of the inhomogeneous quench problem. Both of these exact results rigorously demonstrate a coexistence of ballistic and diffusive transport behaviour in the model, as expected for normal fluids.

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Reševanje kaotičnega kvantnega mnogodelčnega modela

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Ko govorimo o rešljivih modelih, imamo običajno v mislih proste ali integrabilne modele. Ti modeli imajo mnoge posebne lastnosti, ki se razlikujejo od lastnosti generičnih sistemov, ki se obnašajo kaotično.

Pokazal bom, kako nam je s pomočjo posebne lastnosti dualne točke brcanega Isingovega modela uspelo izračunati spektralni form faktor in časovni potek entropije prepletenosti za kaotični kvantni mnogodelčni sistem. Spektralni form faktor nam pokaže, da je model kaotičen ne glede na velikost nereda v magnetnem polju v z smeri. Časovni potek entropije prepletenosti nam pove, da se informacija v modelu širi z maksimalno hitrostjo in doseže maksimalno vrednost.

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Solving Chaotic Quantum Many-body System

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When talking about solvable models, we usually have in mind free and integrable models. These models have many special properties, which are different from those of the generic models that are chaotic.

I will demonstrate how using a special property of the duality point of the kicked Ising spin chain, we managed to compute the spectral form factor and the time evolution of the entangelment entropy for a chaotic quantum many-body system. The spectral form factor shows that the model behaves chaotically for any disorder in the magnetic field in the z direction. The dynamics of the entangelment entropy indicates that the information spreads with a maximal speed and saturates to the maximum value.

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Belle II - prve izkušnje

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V predavanju bom najprej predstavil motivacijo za naslednjo generacijo poskusov v fiziki težkih kvarkov in leptonov, iskanju signalov fizikalnih procesov, ki jih ne moremo zadovoljivo popisati v okviru Standardnega modela, teorije osnovnih delcev in njihovih interakcij. Sledil bo pregled najbolj zanimivih trenutkov pri nastajanju novega detektorja ter rezultati prvih meritev. Na koncu bom predstavil še načrte za bodočnost.

Belle II - first experience with a new detector

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In the talk we will first discuss the motivation for the next generation of experiments in heavy flavour physics, searches for phenomena that cannot be accommodated in the Standard model, the theory of elementary particles and their interactions. We will then present some interestings steps in the construction of the Belle II spectrometer, and discuss the first experience with the next generation detector. We will finish by our plans for the future.

KPZ fizika v kvantni Heisenbergovi spinski verigi

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Predstavil bom pojav KPZ (Kardar-Parisi-Zhang) fizike v kvantni Heisenbergovi spinski verigi ter njeni Troterizirani verziji, ki omogoča enostavnejo numerično obravnavo.

KPZ physics in the quantum Heisenberg spin chain

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I will present the emergence of KPZ (Kardar-Parisi-Zhang) physics in the quantum Heisenberg spin chain and it's integrable Trotterization, which allows for simpler numerical treatment.

Struktura, velikost in statistične lastnosti kaotičnih komponent v Hamiltonskem sistemu z mešanim faznim prostorom

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Generični Hamiltonski dinamični sistemi niso ne integrabilni ne popolnoma kaotični. Ali bo gibanje kaotično ali ne zavisi od začetnega pogoja. Fazni prostor je razdeljen na več invariantnih komponent. V tipičnem primeru kaotična komponenta, imenovana tudi kaotično morje, obdaja neskončno število regularnih komponent, imenovanih Kolmogorov-Arnold-Moserjevi (KAM) otoki [1]. Struktura kaotične komponente je zato tipično zelo zapletena. V tovrstnih dinamičnih sistemih je pogost tudi pojav lepljivosti [2]. Zapletena struktura kaotične komponente in lepljivost predstavljata precejšnjo oviro pri natančnem določanju njene velikosti. Motivacija za določitev velikosti kaotične komponente izvira tudi iz področja kvantnega kaosa, ker je pomemben parameter pri preučevanju spektrov ekvivalentnega kvantnega sistema v semiklasični limiti [3, 4, 5].

Na predavanju bomo predstavili statistične lastnosti največje kaotične komponente v enoparametrični družini biljardov [6, 7]. S spreminjanjem parametra lahko dobimo vse od popolnoma regularnega (integrabilnega) do popolnoma kaotičnega (ergodičnega) Hamiltonskega sistema. Fazni prostor razdelimo na mrežo celic in z iteracijami kaotične orbite določimo katere celice pripadajo kaotični komponenti. Dinamiko polnjenja celic primerjamo s tako imenovanim naključnim modelom [8], ki predpostavlja popolnoma nekorelirane obiske celic in dobro opiše polnjenje celic ergodičnih sistemov. Pokazali bomo, da naključni model zaradi pojava lepljivosti ne more opisati dinamike polnjenja celic v sistemih z mešanim faznim prostorom. Določene asimptotske lastnosti sistema, kot je porazdelitev zasedenosti celic in povprečni časi vračanja so še vedno dobro opisani s tem modelom, kar omogoča določitev velikosti kaotične komponente.

Reference

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Structure, size and statistical properties of chaotic components in a mixed-type Hamiltonian system

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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]. The chaotic component thus exhibits a very complex structure. In dynamical systems of this type the phenomenon of stickiness [2] is usually also present. Both the complex structure of the phase space and stickiness pose a serious obstacle in determining the size of the chaotic component. Additional motivation for determining the size of the chaotic component is provided by quantum chaos, as it is an important parameter in the study of the spectra of the equivalent quantum system in the semiclasical limit [3, 4, 5].

In the talk we will present the statistical properties of the largest chaotic component in a single parameter family of billiards [6, 7]. By changing the value of the parameter, we may acquire anything from a fully regular (integrable) to a fully chaotic (ergodic) Hamiltonian system. 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 [8], 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 with mixed phase spaces. Certain asymptotic properties like the distribution of cell occupancies and average cell return times are still well described with the random model, which enables us to determine the size of the chaotic component.

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Modeliranje sovisnega vpliva planarne celine polarizacije in mehanskih medcelinih interakcij v planarnih tkivih

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Natančna strukturna organizacija epitelijskih celic je pomembna za pravilno delovanje in nadaljnji razvoj različnih tkiv [1]. Mehanizem pakiranja epitelijskih celic je povezan z mehanskimi interakcijami med celicami, ki tkivo vodijo v stanje najnižje mehanske energije [2]. Ob mehanskih interakcijah je pomemben način organiziranja planarna celična polarnost (PCP), ki zagotavlja orientacijsko usmerjanje celic. Signalizacijski mehanizem PCP je posledica asimetrične porazdelitve nekaterih transmembranskih proteinov, ki jih razporejajo specifične znotrajcelične signalne poti [3,4]. Pokazano je bilo, da mutacije in druge motnje v PCP signalizaciji povzroajo popačeno citoarhitekturo epiteljnega sloja. Mutantne celice z motnjami aktivnosti signalnih proteinov predstavljajo topološke napake, kar lahko privede do disfunkcij v delovanju tkiv [5]. Eksperimentalno je bilo pokazano, da so v bližini mutiranih celic [6] prisotne razlike napetosti vezi med celicama. Slednje nas je motiviralo razviti matematični model, ki združuje procese razvijanja tkiv po konceptu minimiziranja mehanske energije in tudi medcelične polarizacije. Naši rezultati kažejo, da zmanjšanje mehanskih interakcij med normalnimi in mutiranimi celicami epitela predstavlja možen regulatorni mehanizem, ki zmanjšuje vpliv topoloških napak, ki jih povzročajo mutirane celice.

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Modelling the interplay between planar cell polarity signaling and mechanical cell-cell interactions in planar tissues

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A precise structural organization of epithelial cells is needed for a proper functioning and development of different tissues [1]. The epithelial cell packing mechanism is associated with mechanical interactions between cells which place the tissue in a state of the lowest mechanical energy [2]. In addition, the planar cell polarity (PCP) signaling pathway has been recognized as another important mechanism for epithelial organization that ensures orientational ordering of the cells. PCP is a consequence of an asymmetric distribution of certain transmembrane proteins which is driven by specific intracellular signaling pathways [3,4]. Mutations and other disruptions of these pathways were found to cause an impaired cytoarchitecture of the epithelium layer. Mutant cells with disrupted activities of signaling proteins basically represent topological defects, which can lead to dysfunctions in tissue operation [5]. Motivated by the fact that regional variations of bond tensions were found in the vicinity of mutant cells [6], we implement a computational model that combines the tissue development processes following the concept of mechanical energy minimization and the intracellular polarization. Our results reveal that a decrease in mechanical interactions between normal and mutant epithelium cells represents a conceivable regulatory mechanism that diminishes the impact of topological defects caused by mutant cells.

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Tisočletje likovne umetnosti skozi oči fizike

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Dvajseto stoletje se pogosto opisuje kot stoletje fizike. Dejansko bi brez fundamentalnih raziskovalnih prebojev v fizikalnih laboratorijih širom po svetu človeška družba danes zagotovo bila zelo drugacna kot je sedaj [1,2]. Kar je preteklih 100 let bilo za fiziko, je preteklo tisočletje bilo za likovno umetnost. Od bizantinske umetnosti, renesanse in realizma, do popa, zadnjih 1000 let je gostilo nekatera umetniško najbolj produktivna obdobja našega obstoja. Masovna digitalizacija likovnih del nam danes omogoča natančno kvantitativno analizo zgodovine likovne umetnosti, in to na zelo obsežni časovni in prostorski skali. V študiji, ki jo bom predstavil [3], smo analizirali več kot 140000 likovnih del od več kot 2300 umetnikov, ki so bile ustvarjene med leti 1031 in 2016. Na podlagi kompleksnosti in entropije prostorskih vzorcev v likovnih delih smo uspeli slednje hierarhično kategorizirati v dvo-dimenzionalnem prostoru reda-nereda in enostavnosti-kompleksnosti, kar nam razkrije časovni razvoj likovne umetnosti, ki se ujema za najpomembnejšimi umetniškimi obdobji preteklega tisočletja. Študija tako nakazuje naslednji korak v analizi masovnih podatkovnih baz, kjer se oddaljujemo od tekstovne semantike [4] in približujemo kvantifikaciji subjektivnih lastnosti del kot so estetika in privlačnost.

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A millennium of visual arts through the eyes of physics

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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. Our research indicates a shift in data science, away from semantics [4] towards the quantification of more subjective properties of artworks like aesthetics and beauty.

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Ohranjevalci posplošene entropije konveksnih kombinacij stanj

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Tako imenovani ohranjevalci so preslikave med strukturiranimi množicami (npr. algebrami, vektorskimi prostori, konveksnimi množicami), ki ohranjajo izbrane lastnosti elementov domene; ohranjajo npr. kako množico, funkcijo ali relacijo v naslednjem smislu: če ima element domene ali skupina elementov izbrano lastnost, imajo to lastnost tudi njihove slike. Študij takih preslikav nam pogosto omogoči karakterizacijo algebrajsko pomembnih preslikav ali pa preslikav, ki so takim blizu, npr. izomorfizmov, jordanskih izomorfizmov, jordanskih $*$-izomorfizmov, ipd., in to le z njihovimi ohranjevalskimi (običajno nealgebrajskimi) lastnostmi. Pozitiven sebi adjungiran linearen operator s sledjo ena, delujoč na realnem, kompleksnem ali kvaternionskem Hilbertovem prostoru H, imenujemo *stanje*. Množico vseh stanj na H bomo označili z $S(H)$. Obravnavali bomo preslikave $\phi : S(H) \to S(H)$, kjer je H končnorazsežen Hilbertov prostor, ki na vseh konveksnih kombinacijah stanj ohranjajo vrednosti določene entropijske funkcije, recimo Shannonovo ali pa katero drugo entropijsko funkcijo. Izkaže se, da morajo take preslikave ohranjati konveksne kombinacije, natančneje, biti morajo oblike $X \mapsto UXU^*$, kjer je U neka realno linearna izometrija na H. Predstavili bomo tudi najnovejše izsledke raziskav.

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Preservers of generalized entropy of convex combinations of states

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The so-called preservers are maps between structured sets (e.g. algebras, vector spaces, convex sets) which preserve certain properties of elements in the domain of the map. Typically, such a map can preserve a set, a function or a relation in the following sense: If the elements of the domain have a chosen property, then also their images have the same property. Studying such maps often leads to characterization of algebraically important maps or maps being close to such maps, for example, isomorphisms, Jordan isomorphisms, Jordan $*$-isomorphisms, etc, only by their (non-algebraic) preserving properties. Positive linear trace-one operator acting on a real, complex or quaternion Hilbert space H, is called *state* or *density operator*. The set of all density operators on H will be denoted by $S(H)$. With H being a finite-dimensional Hilbert space, we consider maps $\phi : S(H) \to S(H)$, which preserve the values of an entropy function, say Shannon or some other, on every convex combination of density operators. It turns out that such a map must preserve all convex combinations of density operators, more precisely, it must be of of the form $X \mapsto UXU^*$, where U is a fixed real isometry of H. We present also the recent development of the topic.

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Quantum chromodynamics in the domain of spontaneously broken chiral symmetry

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The fundamental quantum field theory of strong interactions, quantum chromodynamics (QCD), has not yet been amenable to a universally valid solution, despite tremendous efforts invested now over more than four decades. Depending on energy/momentum, temperature, and pressure QCD is obviously governed by distinct degrees of freedom. For instance, it has been learned relatively fast that in the high-energy regime perturbative methods work reliably, due to the property of asymptotic freedom at zero or low temperature. However, in other areas of the QCD phase diagram different scenarios are obviously met. Especially at high temperatures quarks appear to remain confined beyond the chiral-restoration line and a particular chiral-spin symmetry prevails [1,2].

At low energies QCD is characterized by the spontaneous breaking of chiral symmetry. The corresponding dynamics can be viewed as resting on altered degrees of freedom, namely constituent quarks with dynamical masses and Goldstone bosons, instead of current quarks and gluons. I will discuss the construction of a universal framework for the description of low-energy baryons along a Poincarè-invariant formalism taking into account this kind of dynamics. In particular I will present a relativistic constituent-quark model based on Goldstone-boson exchange, show to which extent it works for all known baryons, and hint to its extension for a realistic description of baryon resonances with proper decay characteristics.

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Letala na električni pogon - izziv prihodnosti

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Potniški letalski promet doživlja hiter in konstanten porast in se vsakih 15 let podvoji. Glavna Evropska letališča bodo kmalu dosegla polno kapaciteto in bodo morala zavračati nove potencialne polete. Glavni razlog, ki preprečuje širjenje glavnih letališč je okoljevarstveni, saj okoliški prebivalci močno nasprotujejo povečanju hrupa in onesnaženosti zraka. Ena od možnih rešitev bi bila elektrifikacija letal. Opisala bom torej omejitve in možnosti uporabe alternativnih goriv v potniškem letalstvu za majhna, do 70 sedežna letala.

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Electrification of aeroplanes - future challenges

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Passenger aircraft industry is fast and steady growing and doubles every 15 years. Main European hubs will soon reach maximum capacity and would be forced to reject potential aeroplane lines. The main reason that prevents further extension of airports capacities is ecological. Most large hubs are mainly situated near the large cites and their residents are against further increasement of air and noise pollution. One of the solutions to prevent or reduce noise and air pollution would be an electrification of aeroplanes. The possibilities and restrictions of usage of alternative fuels in small, up to 70-seater aeroplanes will be discussed.

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Reverzibilni celični avtomati in neravnovesna statistična mehanika

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Izpeljava ireverzibilnih makroskopskih statističnih zakonov, kot so npr. Fourierov ali Fickov zakon, iz reverzibilnih mikroskopskih enačb gibanja, je eden od osrednjih fundamentalnih problemov statistične fizike. V zadnjih letih smo bili priča izrazitemu napredku pri razumevanju dinamike in neravnovesne statistične fizike integrabilnih sistemov [1], zato si obetamo, da bi lahko omenjeno povezavo razumeli vsaj za določene razrede netrivialnih integrabilnih sistemov z močno interakcijo.

V predavanju bom predstavil družino reverzibilnih celičnih avtomatov, ki modelira sisteme interagirajočih delcev, za katero lahko dokažemo obstoj difuzije in točno rešimo več zanimivih paradigm statistične fizike, npr. neravnovesna stacionarna stanja sistema med dvema stohastičnima rezervoarjema [2], problem relaksacije v neravnovesno stacionarno stanje [3], ali celo problem eksplicitnega časovnega razvoja makroskopskih stanj, oz. konkretno izračuna t.i. nehomogenega kvenča in dinamičnih korelacijskoh funkcij v visokoentropijskih ravnovesnih stanjih [4,5].

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Reversible Cellular Automata and Statistical Mechanics

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Derivation of macroscopic statistical laws, such as Fourier's, Ohm's or Fick's laws, from reversible microscopic equations of motion is one of the central fundamental problems of statistical physics. In recent years we have witnessed a remarkable progress in understanding the dynamics and nonequilibrium statistical physics of integrable systems [1]. This encourages us to attempt to understand the aforementioned connection at least in specific classes of nontrivial integrable systems with strong interactions.

In my talk I will introduce a family of reversible cellular automata, which model systems of interacting particles, and for which we can prove the existence of diffusion and exactly solve several interesting paradigms of statistical physics, e.g.: [2] nonequilibrium steady states of the system between two stochastic reservoirs, [3] the problem of relaxation to the nonequilibrium steady state, or even [4,5] the problem of explicit time evolution of macroscopic states, for instance, the solution of inhomogeneous quench problems and the calculation of dynamical structure factor in highly entropic equilibrium states.

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Stabilnost neadiabatnih holonomnih transformacij kvantnih bitov

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Ena od obetavnih metod manipulacije in transformacij kvantnih bitov, ki so osnovni gradniki naprav za kvantno obdelavo informacije, je uporaba Rashbovega pojava. Pri tej metodi odigra vlogo magnetnega polja, ki bi ga bilo nemogoče uporabiti na zelo majhnem področju, sklopitev spina s tirnim gibanjem elektronov. Elektroni v teh časovno odvisnih sistemih pridobijo kvantne faze, ki so posplošitev znane Berryjeve faze. S pomočjo točnih unitarnih transformacij [1] smo dokazali, da pri teh procesih lahko razmerje med neadiabatno Anandanovo in adiabatno fazo Wilczeka in Zeeja zavzame katerokoli realno število [2]. Pokazali smo tudi, da posplošitev na časovno odvisne Kramerjeve dublete na kvantnem obroču omogoča pokritost celotne Blochove sfere [3]. Točno je mogoče analizirati tudi stabilnost in zvestobo transformacij (angl. "fidelity") in kot primer bomo pokazali rezultate vpliva obarvanega šuma tipa Ornsteina in Uhlenbecka, kjer je beli šum znan posebni primer [4]. Prikazali bomo tudi, kako je mogoče obravnavane neadiabatne sisteme sklopiti s termalno kopeljo. Tudi tukaj unitarne transformacije omogočajo točno obravnavo, s preslikavo v Floquetovo bazo in z izpeljavo ustrezne Lindbladove enačbe. Na kontretnem primeru bomo prikazali tipične rešitve [5].

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Stability of non-adiabatic holonomic qubit manipulations

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A promising method of qubit malipulation in quantum information processing applications is the manipulation where the Rashba effect in non-adiabatic systems induces quantum phases, including the spin rotation. By the virtue of exact unitary transformations [1] we prove that the ratio of the non-adiabatic Anandan phase and the adiabatic Wilczek-Zee counterpart can be tuned to any real number [2]. It is demonstrated also that the results can be generalised to time-dependent Kramers doublet states on a quantum ring with tuneable spin-orbit interaction which proves that any qubit transformation on the Bloch sphere is feasible in this system [3]. Stability properties of qubit transformations and the corresponding fidelity can also be studied exactly and as an example we present results for spin-orbit dynamics influenced by the Ornstein-Uhlenbeck coloured noise of driving fields [4]. Finally we demonstrate how these non-adiabatic systems can be coupled to thermal baths. In particular, by the known unitary transformation [1] the system can be expressed in the Floquet basis which enables an exact derivation of the Lindblad equation. Some typical solutions of the corresponding Lindblad equation will be presented [5].

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Analiza parametrično periodično vzbujanega klasičnega in kvantnega linearnega oscilatorja

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Proučujemo, teoretično in numerično, vedenje klasičnega in kvantnega parametrično periodično vzbujanega linearnega oscilatorja. Kot osnovno paradigmo takšnega Floquetovega sistema obravnavamo primer harmonične oscilacije oscilatorjeve frekvence, ki je priročen za teoretično in numerično obravnavo, a ohranja vse splošne lastnosti. Izpeljemo eksplicitno analitično formulo za kvantni propagator s pomočjo klasičnega propagatorja. Uporabljajoč to izpeljemo eksplicitno eksaktno formulo za razvoj pričakovane vrednosti energije, za poljubno normirano začetno stanje. V primeru, ko je začetno stanje stacionarno lastno stanje, je razvoj natančno enak kot za klasični mikrokanonični ansambel začetnih pogojev z isto začetno energijo. Izvedemo popolno numerično analizo vedenja sistema v območjih nestabilnosti (lacunae), kjer se energija oscilatorja eksponentno povečuje, kakor tudi v območjih stabilnosti, še posebej na meji med stabilnostnim ter nestabilnostnim območjem. Numerično potrdimo s popolno zanesljivostjo, da meji med stabilnim in nestabilnim območjem klasično in kvantno *eksaktno* sovpadata, v skladu s teorijo, in dobimo vrsto pomembnih empiričnih rezultatov, še prav posebej enačbo eliptičnega tipa, s katero izrazimo hitrost eksponentnega naraščanja energije v lacunah kot funkcijo drugih sistemskih parametrov. Verjamemo, da so naš pristop in rezultati generičnega tipa, t.j. uporabni v večini tovrstnih linearnih Floquetovih sistemov, in predstavimo motivacijo za splošno teorijo, klasično in kvantno.

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Analysis of the parametrically periodically driven classical and quantum linear oscillator

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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 evolution is exactly the same as for the classical microcanonical ensemble of initial conditions of the same starting energy. We perform a rather complete computational analysis of the system's behaviour inside the instability regions (lacunae), where the energy of the oscillator increases exponentially, as well as in the stability regions, and in particular in the vicinity of the (in)stability borders. 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.

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Periodične rešitve in limitni cikli v nekaterih biokemičnih modelih

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Obravnavamo problem obstoja prvih integralov in bifurkacij limitnih ciklov v tridimenzionalnih sistemih navadnih diferencialnih enačb, ki se pojavljajo pri študiji ekoloških in biokemičnih modelov. Najprej predstavimo pristop, ki omogoča najti invariantne ploskve in Darbouxove integrale v polinomskih sistemih, in ki se lahko uporabljamo tudi za določitev centralnih mnogoterosti sistema. Nato je predstavljena metoda za proučevanje bifurkacij limitnih ciklov na centralni raznoterosti.

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Periodic solution and limit cycles 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 method to investigate limit cycle bifurcations on a center manifold is described.

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Ultralong-Range Molecules

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Ultralong-Range Molecules provide a new type of highly excited Rydberg molecules with a novel binding mechanisms different from the 'traditional' covalent or ionic binding. They combine Rydberg atoms with ground state atoms in a single molecule thereby leading to molecular properties inherited from the Rydberg component. Huge bond lengths and corresponding dipole moments belong to the peculiar features of this species. They have been observed spectroscopically approximately a decade ago and are now under intense investigation in several ultracold atom groups worldwide. Due to their small binding energies they are extremely sensitive even to weak external electric and magnetic fields, as we shall demonstrate in this presentation [1,2,3]. Bond lengths, local equilibria, orientation and aligment can be controlled using fields and vary largely with the degree of excitation of the Rydberg atom(s). We compare experimental results with theory [2] and demonstrate isotropic as well as anisotropic interaction effects with a rich structure of the resulting vibrational dynamics and states. More recently high resolution spectroscopy has even seen the spin structure of those states - and we demonstrate what is necessary in order to describe the latter and combine it with the external field effects [4]. Moving from diatomic to triatomic systems [5,6] the first evidence for three-body interactions has been demonstrated in theory and experiment opening-up the possibility of a full control of chemical reaction dynamics in these highly excited Rydberg molecules.

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Correlation Functions of the Quantum Sine-Gordon Model in and out of Equilibrium

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Complete information on a quantum field theory (QFT) is provided by multipoint correlation functions. However, their theoretical calculation is a challenging problem. If the interaction is strong, perturbation theory fails and more complex approaches have to be developed. This has recently become an experimentally relevant problem, due to progress in cold-atom experiments. In a prominent recent experiment [1], researchers have succeeded in simulating QFT models and directly measuring higher order correlations. In order to provide a theoretical description, we have developed a non-perturbative method [2] to compute correlation functions of the quantum sine-Gordon model, a prototype model of a strongly interacting QFT which is of central interest from both theoretical and experimental point of view. Building upon the so-called Truncated Conformal Space Approach, we numerically construct higher order correlations in a system of finite size in various physical states of experimental relevance, both in and out of equilibrium. We measure deviations from Gaussianity due to the presence of interaction and analyse their dependence on temperature, explaining the experimentally observed crossover between Gaussian and non-Gaussian regimes. We find that correlations of excited states are markedly different from those of thermal states, which can be explained by the integrability of the system. We also study dynamics after a quantum quench, a sudden change in the system, observing the effects of the interaction on the time evolution of correlation functions, their spatial dependence and their non-Gaussianity.

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Towards a Spin Resonance Analogue in Microwave Networks

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The universal properties of chaotic systems are well reproduced by the corresponding properties of random matrix ensembles. Depending on the symmetry with respect to time reversal and the presence or absence of a spin 1/2 there are three universality classes: the Gaussian orthogonal ensemble for systems with time-reversal invariance (TRI) and no spin 1/2 , the Gaussian unitary ensemble for systems with broken TRI, and the Gaussian symplectic ensemble (GSE) for systems with spin 1/2 and TRI. We recently succeeded in an experimental realization of the GSE in microwave networks with a particular symmetry simulating a spin 1/2 system [1,2]. Thus now the whole spin 1/2 world is open to microwave analogue experiments [3]. In particular a microwave simulation of nuclear magnetic resonance should be possible. This means, however, to apply time-dependent variations in the 10 MHz regime to the networks, which is a real challenge. First results towards the realization of this objective will be presented.

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Zmanjšana medcelična povezanost pri sladkorni bolezni tipa 2

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V stanjih zmanjšane občutljivosti tarčnih tkiv na inzulin so opazili ojačane znotrajcelične signale na različnih stopnjah kaskade sklopitve med stimulacijo in sekrecijo v celicah beta in predvideva se, da je ta ojačitev mehanizem hiperinzulinemične kompenzacije med razvojem sladkorne bolezni tipa 2 (Gonzalez, et al. 2013). Ko se občutljivost tarčnih tkiv zmanjša še bolj, se znotrajcelična signalizacija še bolj ojača, zato motnje v znotrajcelični signalizaciji ne morejo v celoti razložiti dekompenzacije v smeri proti polno razviti sladkorni bolezni tipa 2. Pred kratkim so se pojavili dokazi, da v nasprotju z znotrajcelično signalizacijo pride do motenj v medcelični signalizaciji in da bi ta lahko bila primarna tarča diabetogenih faktorjev med razvojem sladkorne bolezni (Irles, et al. 2015; Johnston, et al. 2016). V naši raziskavi smo se odločili poiskati dokaze za moteno medcelično sklopitev med celicami beta pri miših in ljudeh s sladkorno boleznijo. Zapise kalcijevih odzivov na glukozo v celicah beta smo analizirali po kriteriju podobnosti med signali v vsakem izbranem paru celic oziroma med vsakima dvema področjema zanimanja. Na osnovi teh podobnosti smo konstruirali in kvantificirali grafe funkcionalne povezanosti (Stožer, et al. 2013; Gosak, et al. 2018). Tako pri miših kot ljudeh s sladkorno boleznijo so v primerjavi s kontrolnimi osebki vzorci funkcionalne povezanosti pokazali značilno zmanjšano število povezav. Na osnovi tega lahko rečemo, da je medcelična povezanost prizadeta zgodaj v razvoju sladkorne bolezni in bi v prihodnosti lahko postala zanimiva nova terapevtska tarča.

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Decreased Intercellular Connectivity in Type 2 Diabetes

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Augmented intracellular signals at different stages in the stimulus-secretion coupling cascade in insulin-secreting beta cells have been observed in states of decreased insulin sensitivity in target tissues and it is believed that this is the mechanism for the hyperinsulinemic compensation during development of type 2 diabetes mellitus (Gonzalez, et al. 2013). When insulin sensitivity decreases even more, even stronger intracellular signals are detected in beta cells, thus failure in the stimulus-secretion coupling cascade cannot account for decompensation towards frank diabetes. It has been suggested recently that intercellular connectivity, as opposed to intracellular signaling, could be the primary target of diabetogenic insults in pathogenesis of type 2 diabetes (Irles, et al. 2015; Johnston, et al. 2016). In our study, we set out to find evidence of disrupted intercellular connectivity in beta cells from mice and humans with type 2 diabetes. Traces of calcium responses to glucose were analyzed for similarity between every pair of beta cells or every two chosen regions of interest. Based on this similarity, functional connectivity graphs were constructed and quantified (Stožer, et al. 2013; Gosak, et al. 2018). In islets from both mice and humans with diabetes functional connectivity patterns showed a significantly reduced number of connections compared with normal islets. Thus, intercellular connectivity indeed seems to be affected early during development of type 2 diabetes mellitus and could become a new therapeutic target.

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Sklopitev gostote in nematskega reda v izotropnih linearnih polimerih

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Za polimere in druge povezane "linijske tekočine" je značilna makroskopska sklopitev gostote in ravnovesnega nematskega reda, ki jo opisuje *vektorski ohranitveni zakon* Meyer-de Gennesovega tipa [1-5]. Ta pa ne sklaplja fluktuacij teh dveh količin v izotropni fazi, podobno kot v primeru izotropnih tekočin nepovezanih nesferičnih delcev. Šele polni tenzorski opis nematskega reda polimernih talin/raztopin in *tenzorski ohranitveni zakon* [6,7], ki povezuje gostoto in orientacijski red, opišeta sklopljene fluktuacije gostote in nematskega reda tudi v izotropni fazi [7]. Prek te sklopitve krajevna variacija gostote oziroma koncentracije inducira nematski red in s tem akustično oziroma osmotsko dvolomnost v sicer izotropni polimerni talini/raztopini. Teoretične koncepte smo preverili z intenzivnimi simulacijami Monte Carlo izotropnih talin mehkih linearnih verig [5] različnih dolžin in fleksibilnosti, kjer smo primerjali numerično izračunane orientacijske korelacijske funkcije z napovedmi makroskopske teorije [7]. Z vpeljano metodologijo lahko prek mikroskopskih simulacij določimo makroskopske parametre realističnih kontinuumskih modelov specifičnih polimernih materialov.

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Density–nematic coupling in isotropic linear polymers

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Polymers and other connected "line liquids" exhibit a coupling between density and equilibrium nematic order on the macroscopic level that gives rise to a Meyer-de Gennes *vectorial conservation law* [1-5]. Nevertheless, in the isotropic phase they exhibit fluctuations of the density and of the nematic order that are not coupled by this vectorial constraint, just like for isotropic liquids composed of disconnected non-spherical particles. It takes the proper tensorial description of the nematic order in polymer melts/solutions, leading to a *tensorial conservation law* [6,7] connecting density and orientational order, that finally implicates coupled density and nematic order fluctuations, already in the isotropic phase [7]. This coupling implies that a spatial variation of density or a local concentration gradient will induce nematic order and thereby an acoustic or osmotic optical birefringence even in an otherwise isotropic polymer melt/solution. We validate the theoretical conceptions by performing detailed Monte Carlo simulations of isotropic melts of soft worm-like chains [5] with variable length and flexibility, and comparing the numerically determined orientation correlation functions with predictions of the macroscopic theory [7]. The methodology drawn sets forth a means of determining the macroscopic parameters by microscopic simulations to yield realistic continuum models of specific polymeric materials.

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Matrix ansatz for non-equilibrium stationary states

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Understanding systems that are out-of-equilibrium, *i.e.* carrying macroscopic currents of physical quantities (energy, charge, mass,...) is a major challenge of statistical physics. These systems lie beyond the scope of the usual Boltzmann distribution. I will present examples of non-equilibrium stationary states arising in exclusion processes. They are models of particles in interaction on a one dimensional lattice with L sites. The particles are evolving randomly on the lattice following simple stochastic rules. The lattice is connected at its extremities to particle reservoirs with different densities which drive the system out-of-equilibrium. I will explain how to compute exactly the stationary distribution (which does not obey a Boltzmann statistics) in a matrix product form. This will allow us to compute analytically physical quantities such as particle current and correlation functions.

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Kompleksne vijačne strukture v smektičnih fazah iz nekiralnih molekul

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Nizkofrekvenčna resonančna rentgenska spektroskopija (RSoXS) je mogočno eksperimentalno orodje, ki omogoča hkratno preučevanje periodične modulacije elektronske gostote in lokalne orientacijske ureditve molekul. Metoda je tudi edina, ki omogoča preučevanje faz s homogeno elektronsko gostoto in orientacijsko ureditvijo molekul na nanonivoju (npr. nanovijačnice) [1,2]. Kombinacija meritev in modelskih napovedi omogoča zanesljivo napoved faznih struktur.

Predstavila bom raziskavo strukture v smektični fazi, ki jo tvorijo nekiralni upognjeni dimeri [3]. Višje temperaturna faza v tem materialu je zvojno-upogibna nematična faza. Zanjo je značilna homogena elektronska gostota, dolge osi upognjenih dimerov pa se s periodo okoli 10 nm vijačijo po plašču stožca. Ko nižamo temperaturo, dobimo fazni prehod v bolj urejeno, plastno strukturo. S primerjavo RSoXS meritev in modeliranja smo ugotovili, da je struktura 4-plastna (zvojno-upogibna smektična-C faza), ki se dodatno vijači skozi prostor. Obe vrsti modulacije sta značilni za kiralne materiale in zato izjemno presenetljivi v akiralnih sistemih. Z modelom dobimo uvid v dogajanje pri nižjih temperaturah, ki so eksperimentalno nedosegljive. Tako ugotovimo, da z nižanjem temperature interakcije med molekulami želijo vzpostaviti preprosto dvoplastno antiklinsko strukturo.

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Complex helicoidal structure of layered phases made of achiral molecules

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Soft resonant x-ray scattering (RSoXS) is a powerful tool that enables a simultaneous study of the long-range electron density order in combination with the local orientational order of molecules and it is practically the only tool that enables orientational study of molecules in phases with no electron density modulation but nanoscale-ordered orientational (e.g. helical) structure [1,2]. Experimental studies have to be supported by theoretical modelling of the RSoXS response in order to give a reliable prediction of the phase structure.

We present a study of the smectic layer structure formed by achiral bent-core dimers [3]. The upper temperature phase of this material is a twist-bend nematic phase, a phase with a uniform electron density and nano-helical orientational structure of the long molecular axes. When temperature is lowered, a phase transition into a layered, smectic, structure is detected. A comparison of the experimental results with theoretical modelling shows that the structure is a deformed 4-layer twist-bend smectic C phase structure with a long helical pitch superimposed on the 4-layer structure. Both modulations are characteristic for chiral materials and are thus highly surprising in an achiral system. Modelling down to the experimentally unreachable temperatures shows, that the temperature dependence of the structure development in the smectic phase is due to system interactions that tend to unwind the helical structure into a simple anticlinic smectic phase.

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Spinski transport in spodnja meja za Drudejevo utež v Troteriziranem XXZ modelu

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Predstavil bom kvazilokalne ohranjene količine v Troteriziranem/gnanem XXZ modelu in njihov vpliv na spinski transport. Spinski transport v modelu je balističen tudi v območju anizotropij, ki v primeru zvezno-časovnega razvoja pripadajo režimu z vrzeljo.

Spin transport and Drude weight bound in the Trotterized XXZ model

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I will discuss quasilocal conservation laws in the Trotterized/driven XXZ model and their implications on the spin transport. Interestingly, the model exhibits ballistic transport for a range of anisotropies which, in the continuous-time case, belong to the gapped regime.

Topološki linijski defekti kot optični valovni vodniki v nematikih

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Širjenje kompleksnih svetlobnih curkov vzdolž singularnih in ne-singularnih topoloških defektnih linij v nematikih je zanimivo zaradi možne uporabe v fotoniki. Za razliko od opisa širjenja svetlobe skozi regularne mreže kompleksnih defektov, ki temelji na razvoju po valovnih načinih [1], smo se odločili za prilagojeno metodo končnih razlik v časovni-domeni, ki omogoča efektno numerino reševanje Maxwellovih enačb. Posebej zanimivo je, kako se med takim širjenjem svetlobe združujejo topološke invariante nematskega polja in polarizacije [2]. Prav tako je pomembno fokusiranje in razprševanje svetlobnega curka vzdolž defektnih struktur za šibke in visoke svetlobne jakosti [2-4]. V slednjem primeru, smo modelirali tudi samo-preoblikovanje optičnih curkov. Ta pojav temelji na dielektrični sklopitvi v nematskega in električnega polja, kar zahteva simultano numerično reevanje Maxwellovih enačb in enačb za minimizacijo nematske proste energie. Za zakljuek je dodan e opis transformacije femto-sekundnih laserskih impulzov pri širjenju vzdolž defektnih linij.

Reference

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Topological line defects in nematics as optical waveguides

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Propagation of complex light beams along singular and nonsingular topological defects in nematic liquid crystals that is of interest for photonics will be discussed. In contrast to the light propagation through lattices of complex defect structures that are well addressed by wave expansion methods [1], we here used a customized Finite-Difference Time-Domain numerical procedure for solving electro-magnetic equations. We show how during such light propagation, topological invariants of the nematic and polarization fields combine [2]. Focusing and defocusing of the light propagating along such structures are analyzed for both weak and high intensity optical beams [2-4]. In the latter case, we also model the self-reshaping of high intensity optical beams by adding dielectric coupling to the nematic free energy and, in parallel to electromagnetic equations, numerically solve the minimization equations for the free energy of nematic fields. Finally, also transformations of femtosecond laser pulses will be briefly discussed.

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Struktura Galaksije na osnovi letošnjih objav rezultatov satelita Gaia in zemeljskih spektroskopskih pregledov neba

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Aprila je satelit Gaia objavil drugo javno objavo rezultatov, ki s svojo obsežnostjo in točnostjo predstavlja mejnik na skoraj vseh področjih astrofizikalnih raziskav. Po predstavitvi glavnih lastnosti tega podatkovnega seta bom naštel nekaj glavnih odkritij zadnjih mesecev in razultate te satelitske misije povezal z opazovanji z Zemlje, zlasti s spektroskopskim pregledom neba Galah, ki je hkrati objavil največjo bazo kemičnih lastnosti in radialnih hitrosti zvezd doslej. Posebno pozornost bom namenil tudi rezultatom naše raziskovalne skupine.

Reference

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Structure of the Galaxy based on this year's Gaia satellite public data release and results of ground-based spectroscopic surveys

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Size and accuracy of the second data release of the Gaia satellite, published in April, presents a milestone in nearly every field of research in astrophysics. After a brief summary of basic properties of this dataset I will mention some of the more important discoveries of the last months and describe how the unique properties of this data release can be augmented with ground-based observations. Synergy with the Galah spectroscopic survey, which published the largest set of chemical properties and accurate stellar radial velocities, will be discussed, with an emphasis on results of our research group.

References

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