The development of multilayer Laue lenses for extreme X-ray focusing

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The properties of a microscope are determined by the properties of the light source and the quality of the lenses. High resolution X-ray microscopy profited from the development of high brightness X-ray sources and advances in X-ray optics. However, achieving resolutions approaching 1 nm remains a challenge due to the weak interaction of X-rays with the materials of a lens and the extreme precision required in its shape. In this presentation I will talk about the development of multilayer Laue lenses, a diffraction-based X-ray optics, which show promise to efficiently focus hard X-rays potentially down to 1 nm [1]. These lenses are prepared by depositing tens of thousands of nanometer thick layers with utermost accuracy and precision. We developed wavefront interferometry [2,3], which works well even with incoherent laboratory X-ray sources, which we use to measure wavefront aberrations with high sensitivity to get rapid feedback on the quality of the deposition [4]. Using this approach we recently demonstrated lenses that can focus 17.5 keV X-ray photons to below 3 nm [5]. I will show some examples of applications enabled by multilayer Laue lenses with synchrotron or X-ray Free Electron Laser sources and discuss a path to break the 1 nm barrier [6].

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Exact many-body dynamics in quantum circuits via space-time duality

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In recent years, quantum circuits have emerged as useful effective models to understand generic quantum many-body dynamics, and as concrete platforms for quantum simulation. The most appealing feature of these systems is that, contrary to generic many-body systems in continuous time, the dynamics of quantum circuits are sometimes amenable to analytical treatment. In the talk I will present a fruitful route to achieve this goal based on imposing a duality symmetry between space and time. I will review how this symmetry allows to fully characterise entanglement spreading and operator growth and what are its implications on the spreading of quantum information. I will then show that the duality symmetry, and the constraints it imposes, can be systematically relaxed while retaining exact solvability.

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Nanofusion

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I give a review on where nuclear fusion stays to date, what role it may play in the general energy production landscape as a technology using the densest energy per mass. A presentation of the Nanoplasmonic Laser Ignited Fusion Experiment, NAPLIFE, will be given – its ideas, goals, group structure and present results. Experimental findings on laser polymer interaction as crater formation, appearence of excess deuterium and acceleration of protons, all enhanced by nanotechnological manipulations to make possible to form collective plasmonic waves on the surface of nanosize gold metallic pieces. Spectroscopical on-line and off-line methods, like laser induced breakdown spectroscopy (LIBS), Raman spectroscopy of molecular vibrations distingusihnig CH and CD bonds, Thomson parabola measurements on ion masses and energy distributions and nuclear gel detection of energetic particles (CR39) support our hopes to reach fusion reactions at laser intensities available at the Wigner RCP (near threshold) and at ELI-ALPS in Szeged.

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Odtis vezanih elektronskih parov v kotno ločljivi fotoemisijski spektroskopiji

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Analizirali smo elektronsko spektralno funkcijo eno elektronske emisije v Hubbard-Holsteinovem modelu v področju majhnega dopiranja z uporabo metode renormalizacijske grupe z upoarbo gostotnih matrik in točne diagonalizacije nad omejenim variacijskim prostorom. S spreminjanjem jakosti elektronsko fononske sklopitve ter Coulombskega odboja lahko primerjamo rezultate dobljene na podlagi dveh različnih sistemov: tekočine polaronov oziroma bipolaronov. V prvem primeru opazimo spektralno gostoto vse do Fermijeve energije, kot je pričakovano za (nekorelirano) kovino. V primeru tekočine bipolaronov obstaja vrzel v spektralni teži, ki jo določa energija vezave bipolarona, čeprav gre tudi v tem primero za (močno korelirano) kovino. Ta razlika nakazuje, da bi lahko kotno ločljivo fotoemisijsko spektroskopijo uporabili za identifikacijo tekočin predhodno oblikovanih vezanih elektronskih parov. Poleg tega smo pokazali, da lahko tekočino bipolaronov dobro aproksimiramo z porazdelitvijo bozonov s trdo sredico, kar se odraža v njihovi specifični zasedenosti znotraj Fermijeve površine [1].

Izračun smo posplošili tudi na izračun primera s končno optično fononsko disperzijo. Na spektralno funkcijo pomembno vpliva disperzija, zlasti v sistemih z močno elektron-fononsko sklopitvijo. Predznak ukrivljenosti fononskega pasu igra ključno vlogo pri porazdelitvi spektralne teže [2].

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Signature of preformed pairs in angle-resolved photoemission spectroscopy

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We use density matrix renormalization group (DMRG) and variational exact diagonalization (VED) to calculate the single-electron removal spectral weight for the Hubbard-Holstein model at low electron densities. Tuning the strength of the electron-phonon coupling and of the Hubbard repulsion allows us to contrast the results for a liquid of polarons versus a liquid of bipolarons. The former shows spectral weight up to the Fermi energy, as expected for a (uncorrelated) metal. The latter has a gap in its spectral weight, set by the bipolaron binding energy, although this is also a (strongly correlated) metal. This difference suggests that angle-resolved photoemission spectroscopy could be used to identify liquids of pre-formed pairs. Furthermore, we show that the liquid of bipolarons is well approximated by an ensemble of bosons that are hard-core in momentum space, filling the states inside the Fermi sea but otherwise non-interacting [1].

We have generalized the calculation to allow for the finite optical phonon dispersion. The spectral function is significantly influenced by the dispersion, particularly in systems with strong electron-phonon coupling. The sign of the curvature of the phonon band plays a crucial role in the distribution of spectral weight [2].

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Damping Effect of Caputo Fractional Time Derivatives in Nonlinear Wave Equations

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In the past few decades, there has been an extraordinary number of papers in the international literature on the application of fractional calculus to a great many differential equations with applications to practically every branch of science. There occurs, however, an important discrepancy between the applications of ordinary and fractional calculus in the case of conservative systems: When fractional time derivatives of the Caputo type are employed, even though the system remains conservative, all solutions are seen to dissipate to zero or a nontrivial bound state, as soon as the order of the time derivative β is less than two [1]. In this talk, I will explore this phenomenon further and describe its unexpected manifestations in the case of breather solutions of a Klein Gordon nonlinear wave equation [2]. Varying the Riesz spatial derivative α, I will show that, depending on whether it is below or above the value $\alpha = 2$, one finds monotonically attracting kinks, as well as non-monotonic and potentially attracting or repelling kinks, with a saddle equilibrium separating the two.

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Macromolecular Imaging with X-ray free-electron lasers

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The pulses from X-ray free-electron lasers are a billion times brighter than the brightest synchrotron radiation beams available today. When focused to micron dimensions, such a pulse destroys any material, but if the pulse is short enough then the effect on the scattering pattern due to this interaction can be avoided. This mode of "diffraction before destruction" yields high-resolution structural information from proteins that cannot be grown into large enough crystals or are too radiation sensitive for high-resolution crystallography [1]. This has opened up a new methodology of serial femtosecond crystallography for radiation damage-free structures without the need for cryogenic cooling of the sample, and for following the dynamics of photoactive proteins in time [2]. The ability to record diffraction of biological materials using extremely intense and spatially coherent X-ray pulses has also been of interest for imaging non-crystalline samples, such as virus particles and single molecules [3]. The low signal levels pose challenges, and we have been developing hybrid approaches to zero in on single molecules in crystals [4,5]

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Exotic Planetary Systems

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In this communication I will present exotic planetary systems which are about 130 of the more than 7000 known planets in extrasolar planetary. Already the first discovered system was very exotic: 3 Earth sized planets are moving around a pulsar which was a discovery of a Polish astronomer in 1992. For the first discovery of planets around 'normal' stars two Swiss astronomers got the Nobel prize in 1995. I will define what we understand is a normal planetary system compared to exotic ones: planets are moving in retrograde orbits compared to the other ones in that system or there are many planets separated by mean motion resonances.

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Anomalije mezonov B kot znanilci nove fizike

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Standardni model je izjemno uspešen kot teorija elektromagnetne, šibke in močne interakcije med osnovnimi delci. Kljub temu ne razloži mas nevtrinov, temne snovi in zato menimo, da obstaja teorija, ki ga nadgrajuje. Odstopanja rezultatov meritev od napovedi standardnega modela vplivajo na nastanek novih teoretičnih razlag in ustreznih teorij nove fizike. Gre za opis novih interakcij in vključitve novih delcev. V predavanju bom naredila pregled eksperimentanih rezultatov, ki so zbujali največ pozornosti teoretičnih fizikov, s poudarkom na razpadih mezonov B. Predstavila bom napovedi v okviru standardnega modela. Odstopanja med eksperimentalnimi in teoretičnimi rezultati so lahko znanilci nove fizike. Pri prehodu do nove teorije uporabimo efektivno teorijo standardnega modela. V predavanju bom predstavila vlogo hipotetičnih delcev - leptokvarkov - pri iskanju novih teorij in omejitve na njihove lastnosti, ki sledijo iz poskusov pri nizkih in visokih energijah.

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B-meson anomalies as harbingers of new physics

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The Standard Model is remarkably successful as a theory of the electromagnetic, weak, and strong interactions between elementary particles. Still, it doesn't explain the masses of neutrinos and dark matter, so there is an extension of the Standard Model. Deviations of measurement results from the standard model's predictions influence the emergence of new theoretical explanations and corresponding theories of new physics. It enables the description of new interactions and the inclusion of new particles. In the talk, I will overview the experimental results that attracted the most attention from theoretical physicists, emphasising the decay of B mesons. I will present predictions within the framework of the Standard Model. Discrepancies between experimental and theoretical results can be harbingers of new physics. In the transition to the new theory, we use the effective theory of the standard model. Therefore, I will present the role of hypothetical particles - leptoquarks - in the search for new theories and limitations on their properties, which come from experiments at low and high energies.

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Integrabilnost polinomskih diferencialnih sistemov z metodo napihovanja

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Predstavila bom učinkovito metodo za dokazovanje integrabilnosti nekaterih ravninskih polinomskih diferencialnih sistemov. Metoda temelji na uporabi t. i. transformacije napihovanja in reševanju rekurzivnih diferencialnih enačb z uporabo indukcije. S to metodo rešimo nekatere odprte probleme o integrabilnosti v sistemih z resonantnim sedlom. V zadnjem času je bilo pridobljenih tudi nekaj rezultatov o metodi napihovanja v trirazsežnih sistemih navadnih diferencialnih enačb.

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Integrability of polynomial differential systems via blow-up method

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I shall discuss an effective method for proving integrability of some planar polynomial differential systems. The method is based on the use of a blow-up transformation and solving the recurrence differential equations using induction. Using this method some open integrability problems for certain resonant saddles are solved. Recently, some results on the blow-up method in three-dimensional systems of ordinary differential equations have also been obtained.

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Mrežne analize in fenomenološki modeli kot ključ do razumevanja kompleksne dinamike v ansamblih celic beta

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Fenomenološki modeli igrajo ključno vlogo pri preučevanju kompleksnih bioloških sistemov. Z zagotavljanjem poenostavljene, vendar natančne predstavitve realnih pojavov služijo kot most med podrobnostmi bioloških sistemov in našim razumevanjem njihovih osnovnih principov. Ta abstrakcija nam omogoča izluščiti temeljne uvide, razkriti osnovne mehanizme ter olajšati globje razumevanje dinamike sistema. Poleg tega poenostavlja interpretacijo eksperimentalnih podatkov, kar omogoča prepoznavanje organizacijskih principov in vzorcev delovanja. V tem prispevku bom predstavil, kako se lahko fenomenološki modeli uporabljajo za preučevanje zapletenosti dinamike v omrežjih celic beta. V teh večceličnih enotah več sto celic beta, ki delujejo sinhrono in proizvajajo sekretorne pulze inzulina, hormona ključnega za nadzor presnovne homeostaze. Njihovo kolektivno ritmično aktivnost omogoča medcelična sklopitev, zanjo pa je značilna multimodalnost, ki izvira iz prepleta povratnih zank med različnimi podsistemi. Na naravo kolektivne aktivnosti vpliva tudi njihova funkcionalna heterogenost. Iz teh razlogov je večcelična dinamika populacij celic beta zelo kompleksna. Z uporabo fenomenološkega modela bom najprej pokazal, katere fiziološke determinante je treba upoštevati v modelu, da dosežemo dobro skladnost med modelom in eksperimentalnimi rezultati, ki temeljijo na večcelični konfokalni mikroskopiji in mrežnih analizah [2]. Izkazalo se je, da lahko model dobro reproducira eksperimentalno opažene kompleksne dinamične vzorce, če so vključeni kombinacija heterogenih in stimulusno-odvisnih časovnih zamikov, variabilnost ravni ekscitabilnosti celic in heterogena sklopitev [1]. V nadaljevanju bomo model nadgradili z vključitvijo počasne oscilatorne komponente, ki jo upravlja paradigmatski Poincaréjev oscilator in odraža metabolno aktivnost beta celic. To nam omogoča preučevanje, kako kombinacija električne in metabolne sklopitve uravnava kolektivno ritmično aktivnost in kako se le-ta odraža na strukturi funkcionalnih mrež celic beta. Izgleda, da lahko električna sklopitev sama po sebi sinhronizira odzive, medtem ko vključitev metabolnih interakcij ne le dodatno izboljša sinhronost, temveč tudi razširi prostorski doseg interakcij, poveča število povezav znotraj funkcionalnih mrež in izboljša skladnost z eksperimentalnimi opažanji [3]. Na koncu bom izpostavil, da predlagani pristop fenomenološkega modeliranja, ki vključuje zelo malo parametrov, ni koristen le za pridobivanje vpogledov v osnovne mehanizme ob-

likovanja večceličnih odzivov, ampak tudi opozarja na različne lastnosti, ki jih je treba upoštevati pri izgradnji celovitih in realističnih modelov omrežij celic beta.

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Network analysis and phenomenological models as a key towards undersanding the complex dynamics in ensambles of beta cells

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Phenomenological models play a pivotal role in the study of complex biophysical systems. By providing a simplified yet accurate representation of real-world phenomena, they serve as a bridge between the intricate details of biophysical systems and our comprehension of their essential principles. This abstraction allows us to extract fundamental insights, reveal underlying mechanisms, and facilitate a deeper understanding of the system's dynamics. Moreover, it simplifies the interpretation of experimental data, making it easier to identify patterns and organizing principles. In this contribution I will present how phenomenological models can be used to decipher the intricacies of beta cell network dynamics. In these multicellular networks several hundred of beta cells work in synchrony to produce secretory pulses of insulin, a hormone crucial for controlling metabolic homeostasis. Their collective rhythmic activity is facilitated by intercellular coupling and affected by their multimodal activity due to networked feedback interactions of various oscillatory subsystems as well as by their functional heterogeneity. Consequently, the multicellular dynamics of beta cell populations is far from elemental and is characterized by intricate patterns of activity. Using a phenomenological model, I will first show which physiological determinants need to be considered in the model to achieve good agreement between the model and experimental results based on multicellular confocal microscopy, supported by network analyses [2]. It turned out that the model can firmly reproduce the experimentally observed complex dynamical patterns if a combination of heterogeneous and stimulus-dependent time lags, variability in excitability levels and a heterogeneous coupling are incorporated [1]. Next, we upgrade the model by incorporating the slow oscillatory component, which is governed by the paradigmatic Poincaré oscillator and reflects the metabolic activity of beta cells. This eases us to investigate how the combination of electrical and metabolic coupling generates collective rhythmicity and shapes functional beta cell networks. It appears that, while electrical coupling alone can synchronize the responses, the inclusion of metabolic interactions not only further improves coordination but also expands the spatial range of interactions, increases the number of connections within the functional networks, and en-

hances the alignment with experimental observations [3]. I will conclude by emphasizing that the proposed phenomenological modelling approach that involves very few parameters is not only beneficial for getting insights into basic mechanisms that shape the multicellular responses, but also points out the various attributes that should be considered by building up comprehensive and realistic models of beta cell networks.

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Kvantni izvor Ohmove recipročnosti in njena kršitev: prevodnost kot inverzna upornost

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Konvencionalna modrost nas uči, da je električna prevodnost materiala obratno sorazmerna z njegovo upornostjo. Na tem predavanju bom pokazal, da v kvantni teoriji polja, kjer sta oba transportna koeficienta definirana s Kubovimi relacijami dvotočkovnih korelatorjev ohranjenih tokov, Ohmova relacija recipročne odvisnosti na splošno ne velja v teorijah z dinamičnim elektromagnetizmom. Nato bom pojasnil, kako se v nekaterih posebnih primerih (npr. v limiti enosmernega toka ob prisotnosti termalnih efektov, v nekaterih 2+1-dimenzionalnih konformnih teorijah in v holografskih supersimetričnih teorijah) ponovno vzpostavi Ohmova recipročnost. Pokazal bom tudi, da če je odziv materiala izmerjen glede na celotno električno polje, ki vključuje kvantne popravke, potem je Ohmova recipročna relacija po definiciji izpolnjena. Vendar pa so v tem primeru transportni koeficienti podani s polarizacijo vakuuma in ne s korelatorji ohranjenih tokov, ki opisujejo fiziko hidrodinamskega makroskopskega transporta na dolgih razdaljah.

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Quantum origin of Ohm's reciprocity relation and its violation: conductivity as inverse resistivity

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Conventional wisdom teaches us that the electrical conductivity in a material is the inverse of its resistivity. I will show that when both of these transport coefficients are defined in linear response through the Kubo formulae as two-point correlators of conserved currents in quantum field theory, this Ohm's reciprocity relation is generically violated in theories with dynamical electromagnetism. I will then elucidate how in certain special limits (e.g., in the DC limit in the presence of thermal effects, in certain $2+1d$ conformal theories, and in holographic supersymmetric theories) the reciprocity relation is reinstated as an emergent property of conductive and resistive transport. I will also argue that if the response of a material is measured with respect to the total electric field that includes quantum corrections, then the reciprocity relation is satisfied by definition. However, in that case, the transport coefficients are given by the photon vacuum polarisation and not the correlators of conserved currents that dominate the hydrodynamic macroscopic late-time transport.

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Quantum and Classical Dynamics with Random Permutation Circuits

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Understanding thermalisation in quantum many-body systems is among the most enduring problems in modern physics. A particularly interesting question concerns the role played by quantum mechanics in this process, i.e. whether thermalisation in quantum many-body systems is fundamentally different from that in classical many-body systems and, if so, which of its features are genuinely quantum. I will talk about a recent work [1], where we studied this question in minimally structured many-body systems which are only constrained to have local interactions, i.e. local random circuits. In particular we introduced a class of random permutation circuits, where the gates locally permute basis states modelling generic microscopic classical dynamics, and compared them to random unitary circuits, a standard toy model for generic quantum dynamics. Random permutation circuits permit the analytical computation of several key quantities such as out-of-time order correlators, or entanglement entropies. Remarkably, despite the fundamental differences between unitary and permutation dynamics, they exhibit qualitatively similar behaviours.

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From Physics to AI: Perspectives of Digital, Neuromorphic, and Quantum Computing

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In modern machine learning, digital computers only simulate neuronal networks of brains. Their von Neumann architecture separates memory and processor units, for example, and thus leads to considerable energy consumption and environmentally harmful energy dissipation wich contradicts to the Green Deal. Brain-orientated (neuromorphic) computing recreates brain structures with memristive circuit networks and photonic devices that integrate these functions like natural brains with less energy consumption, significant efficiency gains and environmentally friendly. They can be used to model structure and pattern formation in physical, chemical, biological and neurological systems. Recent Nobel prizes of physics (Hopfield and Hinton 2024) highlight the deep rooting of modern machine learning in pattern formation of nature. Pattern and structure formation opens up new applications of pattern recognition with learning algorithms in artificial intelligence. They can be combined with the advantages of quantum computing with quantum parallelism and entanglement by using, e.g., photonic quantum chips. Their principles are also deeply rooted in nature which were recently also highlighted by Nobel prizes in physics (Aspect, Clauser, Zeilinger 2022). We aim at hybrid and sustainable AI in which all these computing paradigms are integrated.

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Integrabilnost in linearizabilnost nekaterih tridimenzionalnih polinomskih sistemov NDE

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Govoril bom o integrabilnosti in linearizabilnosti družine tridimenzionalnih polinomskih sistemov, pri katerih ima matrika linearne aproksimacije lastne vrednosti $1, \zeta, \zeta^2$, kjer je $\zeta^3 = 1, \zeta \neq 1$. Vzpostavljen je kriterij za zagotavljanje konvergence Poincaré-Dulacove normalne forme teh sistemov, obenem pa je podrobno preučena povezava med to normalno obliko in integrabilnostjo. Poleg tega je razvit algoritem za identifikacijo potrebnih pogojev za integrabilnost sistema. Podamo primer uporabe tega algoritma na specifični kvadratni poddružini, kar nam omogoča vpogled v pogoje za integrabilnost in linearizabilnost v tem kontekstu.

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Integrability and linearizability of a family of three-dimensional polynomial systems

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I discuss the local integrability and linearizability of a family of three-dimensional polynomial systems where the matrix of the linear approximation has eigenvalues $1, \zeta, \zeta^2$, where $\zeta^3 = 1, \zeta \neq 1$. A criterion is established to ensure the convergence of the Poincaré–Dulac normal form for these systems, and the link between this normal form and integrability is carefully examined. Furthermore, an efficient algorithm is developed to identify the necessary conditions for system integrability. Application of this algorithm to a specific quadratic subfamily yields insights into the conditions for integrability and linearizability within this context.

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Porazdelitev razmerij razlik nivojev v gobastih biljardih

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Predstavil bom rezultate numerične analize razmerij razlik energijskih nivojev v gobastem biljardu. Le-ta je paradigmatični primer sistema mešanega tipa, ki ima natanko eno kaotično ter eno regularno komponentno, kar pomeni, da v primeru nesignifikantne kontribucije lokaliziranih kaotičnih stanj (območja lepljivosti) lahko pričakujemo Berry-Robnik porazdelitev P(s) razmikov energijskih nivojev s [4], kakor tudi ujemanje analogne teoretične porazdelitve P(r) razmerij r med zaporednimi razmiki (Hua Yan [5]) z numeričnimi rezultati. Analizo smo naredili za 9 enakomerno razmaknjenih vrednosti širine noge, kjer smo pokrili režim od skoraj regularnega do skoraj kaotičnega faznega prostora, do lastnih stanj velikostnega reda 100.000. Ugotovili smo tudi, da pri teh energijah še igrajo vlogo "bouncing ball modes", ki so izvor delne lokalizacije kaotičnih stanj, kar je zelo dobro opisano z Berry-Robnik-Brody porazdelitvijo, s klasičnim eksaktnim Berry-Robnik parametrom, ter prilagojenim Brodyjevim beta parametrom. Efekti te lokalizacije so tem manjši, čim večji je delež kaotičnih stanj.

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Distribution of spacing ratios in mushroom milliards

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I will present the results of the numerical analysis of level spacing ratios in the mushroom billiard. This is a paradigmatic example of a mixed-type system that has exactly one chaotic and one regular component, which means that, in the case of an insignificant contribution from localized chaotic states (sticky regions), we can expect the Berry-Robnik distribution P(s) of energy level spacings s [4] as well as the agreement of the analogue distribution P(r) of the level spacings ratio r (Hua Yan [5]) with the numerical results. We performed the analysis for 9 uniformly spaced values of the stem width, covering the regime from an almost regular to an almost chaotic phase space, for the eigenstates of order 100.000. We found that at these energies the "bouncing ball modes" still play a role, which are the origin of the partial localization of the chaotic states, which is well described with the Barry-Robnik-Brody distribution, with the classical exact Berry-Robnik parameter and the fitted Brody beta parameter. The effects of localization are the smaller the larger the fraction of chaotic states.

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Shapes of the Nucleons

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The nucleons as composite elementary particles are not only subject to the strong forces, which keep them together, but also to electromagnetic, weak, and gravitational interactions. Exposing them to probes of the these latter forces allows to determine/measure their extended structures, i.e. the electromagnetic, weak, and gravitational form factors. For any reasonable theory or model of the nucleons it is not enough to describe just their masses (and possibly their excitation spectra), but they must also reproduce the distributions of electric charge, magnetization, axial charge etc. in agreement with phenomenology.

The relativistic constituent-quark model (RCQM) represents an effective approach of describing the low-energy hadrons on the basis of the fundamental strong interaction, the quantum chromodynamics (QCD). We have constructed such a RCQM through a Poincaré-invariant mass operator, rigorously defined on a Hilbert space. Contrary to a quantum field theory, we thus consider the nucleons as a relativistic system of three constituent quarks, i.e. with a finite number of active degrees of freedom. The dynamics is furnished by the QCD confinement and a Goldstone-boson-exchange (GBE) hyperfine interaction, as suggested by the spontaneous breaking of chiral symmetry (SBχS), a genuine property of low-energy QCD.

I will demonstrate results obtained in this way for covariant electric as well as magnetic form factors, axial/weak form factors, and also gravitational form factors of both the proton and the neutron. Thereby it will become evident that the corresponding structures of the nucleons can only be consistently described in a fully relativistic approach, even though the corresponding observables are measured at low momentum transfers; in particular, Lorentz boost effects may not be neglected. In the case of the nucleons the theoretical predictions can be well tested by experimental data, even with respect to the flavor contents, i.e. the individual quark contributions to the electromagnetic form factors.

We have subsequently extended this kind of studies also to the electroweak form factors of all the other singlet, octet, and decuplet baryon ground states (Δ, Λ, Σ, Ξ, and Ω). If time permits, I will present some selected results, which reveal surprising insights into the flavor compositions of these hyperon states.

Algoritem za prepoznavanje dvojnih zvezd

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Dvojne zvezde so bogat vir informacij za astronome, saj preko svoje dinamike omogočajo določanje podatkov o zvezdah, ki jih ni mogoče pridobiti na druge načine. V določenih primerih so orbite zvezd postavljene tako, da v smeri gledanja z Zemlje, zvezdi izmenično zakrivata ena drugo. To omogoča, da prepoznamo sisteme dvojnih zvezd preko značilnih mrkov, ki so vidni v izsevu. Je pa za takšno prepoznavanje dvojnih zvezd potrebno ročno pregledovanje izsevov, kar vzame veliko časa. Zato smo razvili algoritem, ki združuje več različnih testov in kazalnikov, s pomočjo katerih računalnik lahko avtomatično pregleda na tisoče zvezdnih izsevov in za vsak izsev poda oceno, kolikšna je verjetnost, da prihaja iz zvezde dvojnice.

Delo je bilo opravljeno v sklopu koriščenja sobotnega leta na Univerzi Villanova v Združenih državah Amerike. Zato bom ob svojem raziskovalnem delu o razpoznavanju dvojnih zvezd z vami delila tudi svoje izkušnje o delu na Univerzi Villanova.

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Algorithm for recognizing eclipsing binary systems

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Binary star systems are a treasure trove of information for astronomers, as their dynamic interactions reveal stellar properties that would otherwise remain hidden. In specific orientations, the orbital paths of binary stars cause them to periodically obscure each other as seen from Earth, producing distinctive eclipses in their light emissions. Identifying such eclipsing binaries traditionally requires manual analysis, a time-intensive process. To streamline this, we developed an algorithm that combines multiple tests and indicators, enabling computers to automatically analyze thousands of star fluxes and estimate the probability of flux to come from a binary sistem.

This research was conducted during a sabbatical year at Villanova University in the United States. Alongside insights from my study of binary star detection, I will share my experiences working at Villanova University.

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Kvantni mnogodelčni kaos

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Kvantni kaos (v pretežno enodelčnih sistemih) je bil zelo živahno raziskovalno področje v 1980ih in 1990ih. V zadnjih letih pa se je področje kvantnega kaosa spet zelo oživilo okrog kvantnega mnogodelčnega problema, kar je pritegnilo teoretične fizike iz zelo raznoterih skupnosti, od fizike kondenzirane materije, kvantne optike in kvantne informatike, pa do kvantne gravitacije. Ena od najbolj splošnih in robustnih lastnosti kvantno-kaotičnih sistemov je aplikativnost teorije slučajnih matrik.

Po motivacijskem uvodu v področje kvantnega kaosa se bom posvetil predvsen fascinantnemu problemu presenetljive učinkovitosti teorije slučajnih matrik za popis spektralnih fluktuacij v razsežnih kvantnih sistemih na mrežah. Pred kratkim smo identificirali razred takšnih sistemov z lokalno interakcijo, kjer lahko matematično rigorozno pokažemo ujemanje statističnih fluktuacij lastnih (kvazi)energij, karakterizirano s t.i. spektealnim oblikovnim faktorjem, ter teorijo slučajnih matrik. Takšni *dvojno unitarni sistemi* vsebujejo celotno ergodično hierarhijo dinamičnih režimov, od integrabilnosti, ne-ergodičnosti, do ergodičnosti, mešanja in maksimalnega (kvantnega) kaosa. Dvojno unitarni sistemi omogočajo analitičen izračun prostorsko-časovnih korelacijskih funkcij lokalnih opazljivk in se zelo primerni za eksperimentalni študij v aktualnih kvantnih simulatorjih.

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Quantum Many-Body Chaos

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Quantum chaos (of mostly single particle problems) has been a fruitful interdisciplinary arena of research in 1980s' and 1990s'. In recent years, the field has dramatically revived around the quantum many-body problem gathering very diverse communities of theoretical physicists ranging from condensed matter, quantum optics and quantum information, to quantum gravity. One of the most general characteristics of quantum chaotic systems is the ubiquitous applicability of random matrix theory.

After a general introduction to the field, I will focus specifically on the fascinating problem of 'unreasonable effectiveness' of random matrix theory for description of spectral fluctuations in extended quantum lattice systems. A class of locally interacting spin systems has been recently identified where the fundamental measure of (quasi)energy level fluctuations, the spectral form factor, is proven to match with random matrix theory, and where spatiotemporal correlation functions of local observables as well as some measures of dynamical complexity can be calculated analytically. These, so-called dual unitary systems, include the whole 'ergodic hierarchy' of dynamics: integrable, non-ergodic, ergodic, and generically, (maximally) chaotic cases, and are ideally suited for experimental studies on the current generation of quantum simulators.

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Vpliv okolja na kvantne faze

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Ena izmed 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 sicer 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.

Izkaže se, da se da problem obravnavati tudi sklopljen z okoljem, na primer s termalno kopeljo. Tudi tukaj unitarne transformacije [1] omogočajo točno izpeljavo ustrezne Lindbladove enačbe [2]. Posebne primere se nato da celo točno rešiti v okviru formalizma tretje kvantizacije [3,4]. Na konkretnem primeru bomo pokazali, kako sklopitev kubita z okoljem povzroči karakteristične spremembe kvante faze [5].

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Effects of the environment on the quantum phases

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One of the methods for manipulating and transforming quantum bits, which are the basic building blocks of quantum information processing devices, is the use of the Rashba phenomenon. In this method, the role of a magnetic field, which otherwise cannot be utilised in a very small space, is assumed by coupling the spin with the orbital motion of the electrons. The electrons in these time-dependent systems aquire quantum phases, which are a generalisation of the well-known Berry phase.

It turns out that the problem can also be treated in conjunction with the environment, for example with a heat bath. Here unitary transformations [1] enable the exact derivation of the corresponding Lindblad equation [2]. Special cases can then even be solved exactly within the framework of the third quantisation formalism [3,4]. Using a concrete example, we will show how the coupling of the qubit with the environment causes characteristic changes in the quantum phase [5].

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Pasivna in aktivna topološka mehka snov

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Topološka mehka snov predstavlja posebno vrsto materialov, ki so sposobni različnih materialnih mehanizmov in lastnosti, od notranjega reda, samoorganizacije, topologije, defektov in pomembno tudi aktivnosti. Podal bom izbran pregled nedavnih in nastajajočih smeri v pasivni in aktivni topološki mehki snovi, s posebnim poudarkom na strukturah v pasivnih in aktivnih nematikih ter njihovi sposobnosti delovanja kot fotonski ali mikroelektronski elementi. Singularni in nesingularni topološki defekti se kažejo kot objekti, ki lahko vplivajo ali celo nadzorujejo delovanje in odziv materiala, tako v pasivnih kot aktivnih sistemih.

Passive and active topological soft matter

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Topological soft matter presents distinct class of materials capable of diverse material mechanisms and characteristics, ranging from internal order, self-assembly, topology, defects and notably, activity. Here, I will give a selected overview of recent and emergent directions in passive and active topological soft matter, with particular emphasis on structures in passive and active nematics and their capability to perform as photonic or micro-electronic elements. Singular and nonsingular topological defects are shown to perform as objects that can affect or even control the material performance and response, both in passive and active systems.

Probing and Controlling Many-Body Quantum Chaos

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The notions of chaos and order are central to understanding the statistical physics of many-body systems. Thermalization and the spread of quantum information in many-body dynamics is presently attracting a lot of attention across various fields, ranging from statistical physics via cold atom physics to quantum gravity. Starting from the concept of a "quantum butterfly effect", this includes questions of how many-body quantum interference [1] and scarring [2] affect equilibration, more generally non-classicality in many-particle quantum physics. Vice versa, it is long known how to harness exponential sensitivity to changes in initial conditions for control purposes in classically chaotic systems. We will generalize this concept [3], using chaos as a resource for steering many-body quantum dynamics. We will address the above phenomena using semiclassical methods based on interfering Feynman paths, thereby bridging the classical and quantum chaotic many-body world [1].

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Semiklasično vedenje lastnih stanj v sistemih mešanega tipa

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Predstavil bom obsežno fenomenološko evidenco za semiklasično vedenje lastnih stanj v (generičnih) kvantnih sistemih mešanega tipa, ko proučujemo njihove Wignerjeve in Husimijeve funkcije. V splošnem opazimo čista kaotična stanja, čista regularna stanja in stanja mešanega tipa. Vendar, v semiklasični limiti pojema relativni delež mešanih stanj, kot funkcija efektivne Planckove konstante, kot potenca z eksponentom blizu -0.3 [1-5]. To je povsem v skladu s principom enakomerne semiklasične kondenzacije (PUSC) Wignerjevih in/ali Husimijevih funkcij (v kvantnem faznem prostoru) [6]. Stanja lahko kategoriziramo s pomočjo indeksa prekrivanja M: za povsem regularna stanja imamo $M = -1$, za povsem kaotična stanja $M = +1$, medtem ko za mešana stanja velja $-1 < M < +1$. Pokazal bom evidenco, da so ločena kaotična stanja okoli $M \approx +1$ lahko dinamično lokalizirana. Tedaj je porazdelitev razmikov med sosednjimi nivoji dobro opisana z Brodyjevo porazdelitvijo, medtem ko so pripadajoče lokalizacijske mere porazdeljene v skladu z beta porazdelitvijo. V ultimativni semiklasični limiti efekti lokalizacije izzvenijo, in opazimo vedenje v skladu z GOE/GUE. Ta empirična opažanja so močno podkrepljena z najnovejšimi proučevanji pasastih naključnih matrik [8].

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Semiclassical behaviour of eigenstates in mixed-type systems

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I shall present a vast phenomenological evidence for the semiclassical behaviour of eigenstates in mixed-type (generic) quantum systems, by studying the Wigner and Husimi functions. Generally speaking we observe purely chaotic, purely regular and mixed-type states. However, in the semiclassical limit the relative fraction of mixed-type states decays as a power law as a function of the effective Planck constant, with exponent around -0.3 [1-5]. This is entirely in agreement with the Principle of Uniform Semiclassical Condensation (PUSC) of Wigner functions and/or Husimi functions (in the quantum phase space) [6]. The eigenstates can be categorized by means of the overlap index M: for purely regular states $M = -1$, for purely chaotic states $M = +1$, while for the mixed-type states $-1 < M < 1$ [7]. I shall present the evidence that after the separation of chaotic states around $M \approx +1$ these states can be dynamically localized. Then, their level spacing distribution is well described by the Brody distribution, and their localization measures satisfy the beta distribution. In the ultimate semiclassical limit the localization effects also disappear, and the GOE/GUE behaviour is observed. These empirical findings are strongly corroborated by the very recent studies of banded random matrices [8].

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Periodične rešitve v nekaterih 3-dim sistemih NDE

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Proučujemo prve integrale in periodične rešitve v trirazsežnih sistemih navadnih diferencialnih enačb, ki izkazujejo določene simetrije. Natančneje, raziskujemo obstoj centrov na centralnih mnogoterostih teh sistemov in izpeljemo pogoje za koeficiente, pod katerimi obstajajo takšni centri. Poleg tega podajamo omejitve števila limitnih ciklov, ki lahko bifurcirajo iz centrov ob majhnih motnjah.

Nadalje iščemo sisteme, ki imajo izohrone centre na centralni mnogoterosti. Večina teh sistemov je linearizabilnih na centralni mnogoterosti z Darbouxovimi transformacijami. Opravili smo tudi numerične izračune, ki zagotavljajo primere, kjer je centralna mnogoterost elipsoid ali hiperboloid, napolnjen z neskončno družino izohronih periodičnih orbit. Na podlagi primera vidimo, da je geometrija izohronih centrov v trirazsežnih sistemih lahko precej drugačna od dvodimenzionalnega primera. V dvodimenzionalnih sistemih je namreč periodični isohroni anulus vedno nekompakten, medtem ko smo našli v primeru elipsoida kompakten periodični anulus, napolnjen z izohronimi orbitami.

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Periodic solutions in some 3-dim systems of ODEs

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We study first integrals and periodic solutions in three-dimensional systems of ordinary differential equations admitting some symmetries. Specifically, we investigate the existence of centers on the center manifolds of these systems and derive conditions on the coefficients for existence of such centers. Additionally, we provide bounds on the number of limit cycles that can bifurcate from the centers under small perturbations.

Further, we look for systems having isochronous centers on the center manifold. Most of them are linearizable on the center manifold by Darboux type transformations. We also performed numerical computations providing examples of a center manifold being an ellipsoid and a hyperboloid filled with an infinite family of isochronous periodic orbits. We see from the example that the geometry of isochronous centers in 3-dim systems can be rather different from the 2-dim case. Namely, in the case of planar systems the periodic isochronous annulus is always non-compact, but in the case of the ellipsoid we have a compact periodic annulus filled with isochronous orbits.

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Coherent perfect absorption and transmission of light

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In my talk I will present two recent works focused on the perfect absorption and transmission of waves through interferometric cancellation of backscattering. In the first case [1,2], we demonstrate that even a weakly absorbing film can be turned into a "coherent perfect absorber" by building a degenerate cavity around it. This special cavity perfectly couples incoming light fields with arbitrary wavefronts into the absorber – even for the case that light is a dynamically varying speckle pattern. In the second case [3], we demonstrate how to construct an anti-reflection structure for a complex scattering system like a disordered medium. Similar to an anti-reflection coating for conventional eye-glasses, this structure leads to perfect transmission across the scattering system by suppressing back-scattering for any incoming wavefront. If time permits, I will also say a few words about the topological origin of the above effects and how this aspect can be used to engineer thermal radiation [4].

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Dinamika tekočin, prenos toplote in termodinamika - nekatera razmišljanja povezana s Slovenijo in Slovenci

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Število prebivalcev Slovenije je naraslo s približno enega milijona na začetku 18. stoletja na več kot dva milijona danes. Etnični zemljevid prebivalstva Slovencev v 18. stoletju se je trikrat skrčil in danes obsega 20 271 kvadratnih kilometrov. Prvo ohranjeno pisano besedilo v slovenskem jeziku sega v deseto stoletje. Zato ne preseneča, da smo Slovenci lahko le sorazmerno svoji velikosti prispevali v zakladnico znanosti. Predavanje želi osvetliti delo štirih izjemnih Slovencev in neslovenca, živečega na slovenskih tleh, povezanih s termofluidnimi znanostmi. To so Janez Vajkard Valvasor (1641-1691), Jožef Stefan (1835-1893), Ernst Mach (1838-1916) in Zoran Rant (1904-1972). Valvasorja sem izbral, ker je opisal hidravliko Cerkniškega presihajočega jezera, Stefana zaradi njegovih prispevkov k prenosu toplote s faznimi prehodi, Macha zaradi njegovih poskusov z nadzvočnim tokom, Ranta pa zaradi njegovega prispevka k termodinamiki. Veliko število konceptov in izrazov ima korenine v njihovem delu. Stefanovo število, Stefanov problem, zakon o sevanju, Machovo število, izrazi eksergija in anergija so primeri današnje standardne uporabe. Izbral sem nekaj zanimivih znanstvenih in zasebnih elementov iz njihovih življenj z upanjem, da bodo privlačni za mednarodno fizikalno skupnost in združljivi z božičnim vzdušjem srečanja.

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Fluid dynamics, heat transfer and thermodynamics - some reflections associated with Slovenia and Slovenians

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Slovenia's population grew from about one million at the beginning of the 18th century to above two million today. The ethnic map of where the Slovenians lived in the 18th century has shrunk thrice and amounts to 20 271 square kilometres today. The first preserved written text in the Slovenian language dates back to the tenth century. So, it is not surprising that the Slovenians could in general only proportionally to the size contributed to the overall treasure trove of science. The talk aims to illuminate the work of four exceptional Slovenians and a non-Slovenian living on Slovenian soil associated with thermofluid sciences. These are Janez Vajkard Valvasor (1641-1691), Jožef Stefan (1835-1893), Ernst Mach (1838-1916) and Zoran Rant (1904-1972). I have picked up Valvasor because he described the hydraulics of Cerknica intermittent lake, Stefan, because of his contributions to heat transfer with phase-change, Mach because of his experiments with hypersonic flow, and Rant because of his contribution to thermodynamics. A large number of concepts and terms have roots in their work. The Stefan number, the Stefan problem, radiation law, Mach number, exergy and anergy terms are examples of standard use nowadays. I have selected some interesting scientific and private elements from their lives with the hope of being attractive to the international physics community and compatible with the Christmas atmosphere of the meeting.

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Rydberg physics: From Ultralong-Range Molecules to Quantum Simulation and Quantum Optimization

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A review on the most recent activities in Rydberg physics at the center for optical quantum technologies will be provided. I start out with addressing the exotic properties of ultralong-range Rydberg molecules (ULRM). ULRM possess extreme bond lengths of the order of several micron and huge dipole moments. Their potential energy curves mimic the highly oscillatory structure of the Rydberg wave function thereby offering new possibilities for engineering molecular properties on vastly different time and length scales. Trilobite and butterfly states can easily be controlled by weak external electric or magnetic fields. I demonstrate that synthetic dimensions based on quantum numbers can be used to design conical intersections and consequently non-adiabatic interaction effects in the spectra of ULRMs. Ultrafast decay processes are a consequence of these intersections. Quenches of external fields then lead to a rich rovibrational quantum dynamics of ULRM.

The second part of this talk focuses on quantum simulation and quantum optimization. I provide evidence for novel quantum phases of strongly interacting many-body Rydberg setups, specifically the so-called bond order density wave is unraveled and the extended control of Luttinger liquid phases is presented. On the quantum optimization side I describe how a local detuning approach can enhance the tweezer array-based control of the famous graph theoretical MIS and Max-Cut problems. The traditional order $\propto N^2$ approach is here replaced by a linear system size scaling approach. Finally, I will make a short excursion into our recent work on single atom implementation of integer linear programming. Here, a single Rydberg atom will be used to encode linear and even nonlinear integer problems which are known to be difficult to solve in a classical manner.

Ultra-near integrable systems and quantum tunneling

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What is the essential difference between the tunneling effects of integrable and non-integrable systems? This question can be regarded as a fundamental problem in the quantum mechanics of non-integrable systems, yet it remains far from fully understood even after 40 years since it was first raised. The primary reason for this is that capturing exponentially small quantities, which are non-perturbative in nature, is challenging in a phase space where regular and chaotic motions intricately coexist. Here, through the analysis of the *ultra near-integrable system*, in which the perturbation from the integrable system is extremely small, so that none of the visible structures inherent to non-integrability appear in the classical phase space, we will show that the mechanism of quantum tunneling in non-integrable systems can be clearly distinguished from that in integrable systems. The validity of the so-called *resonance-assisted tunneling* scenario is critically examined.

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Bledeča ergodičnost

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Poročal bom o odkritju novega ergodičnega režima po imenu "bledeča ergodičnost". To je režim, v katerem se kvantni sistem še vedno obnaša ergodično, vendar pa je hkrati tudi znanilec faznega prehoda z zlomom ergodičnosti. Z drugimi besedami, "bledenje" je sinonim za bledeče barve jesenskih listov, ki bodo kmalu padli z drevesa. Domnevamo, da je ta režim generična lastnost kvantnih sistemov, ki se približujejo faznemu prehodu z zlomom ergodičnosti, in torej ne moremo preiti v neergodično fazo, ne da bi najprej ergodičnost zbledela.

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Fading ergodicity

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We uncover a novel ergodic regime dubbed "fading ergodicity". This is a regime in which a quantum system is still ergodic, however, it also acts as a precursor of the ergodicity breaking phase transition. In other words, "fading" ergodicity is a synonym of the "fading" colors of the leafs that are just about to fall off the tree. We conjecture this regime to be a generic property of quantum systems approaching the ergodicity breaking phase transition, and therefore, one cannot make a system nonergodic without first making the ergodicity fade.

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Spectral correlations as signatures of isolated and dissipative quantum chaos

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In this talk, we will explore the role of spectral correlations as indicators of quantum chaos. In isolated quantum systems, these spectral correlations have been interpreted as quantum manifestations of classical chaotic motion [1-3]. However, in dissipative quantum systems, the relationship is not clear in certain cases [4]. Our focus will be on atom-field systems with one and two-photon interactions [5, 6], which are of significant experimental interest and are considered fundamental for the development of quantum technologies.

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Feroelektrični nematiki: materiali z veliko permitivnostjo ali nizko prevodnostjo?

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Nematična faza je tekočekristalna faza z najvišjo simetrijo, ki vsebuje le orientacijski red dolgih osi molekul. Čeprav so molekule polarne, je faza v splošnem nepolarna. Polarna (feroelektrična) nematična faza (N_F) je dolgo časa veljala zgolj kot teoretična možnost, zato je njeno nedavno odkritje [1] takoj pritegnilo široko pozornost. Za N_F fazo so značilni velika spontana električna polarizacija reda velikosti 10^{-2} Cm^{-2}, visoke vrednosti nelinearne susceptibilnosti drugega reda in elektrooptičnih koeficientov ter velik fleksoelektrični učinek. Pomembna značilnost N_F faze je njena izjemno visoka relativna permitivnost ($\sim 10^4$). Ta ogromna vrednost, ki je predmet živahne znanstvene razprave, naj bi bila posledica napačne interpretacije rezultatov dielektrične spektroskopije (DS). Nedavno sta bila predlagana dva modela za opis DS meritev feroelektričnih nematikov v tankih planarnih kondenzatorjih. Prvi model obravnava plast N_F med elektrodama kot material z nizko upornostjo, pri čemer je upornost obratno sorazmerna s kvadratom velikosti polarizacije [2]. Drugi model obravnava N_F material kot material z visoko permitivnostjo [3]. Predstavila bom napovedi obeh modelov in pojasnila, zakaj oba modela enako dobro opišeta večino opaženih rezultatov DS. Vendar pa nekatera eksperimentalna opažanja lahko pojasnimo le z drugim modelom [3].

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Ferroelectric nematics: Materials with huge permittivity or low apparent resistivity?

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Nematic phase is a liquid crystalline phase with the highest symmetry, exhibiting only the orientational order of long molecular axes. Even though the constituent molecules are polar, the phase is, in general, apolar. The polar (ferroelectric) nematic phase (N_F) was long thought of as being only theoretically possible, so its recent discovery [1] immediately attracted a wide research interest. The N_F phase is characterized by a large spontaneous electric polarization of the order of 10^{-2} C/m^2, high values of the second order susceptibility and electrooptic coefficients and a giant flexoelectric effect. A remarkable feature of the N_F phase is its huge relative permittivity ($\sim 10^4$). This huge value is under a lively scientific discussion and is argued to result from a misinterpretation of the dielectric spectroscopy (DS) results. Two models have recently been proposed for the description of DS measurements of ferroelectric nematics in thin planar capacitors. The first model considers the N_F layer between the electrodes as an effective low resistivity material, the resistivity being inversely proportional to the square of polarization magnitude [2]. The second model considers the N_F phase as indeed having a huge permittivity [3]. I will present implications of both models and show that they both describe majority of the observed DS results. However, some experimental observations can be accounted for only by the second model [3].

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Local integrability breaking and exponential localization of leading Lyapunov vectors

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We study integrability breaking and transport in a discrete space-time lattice with a local perturbation. We find that the Lyapunov spectrum of the system exhibits discontinuity at the edge, and the corresponding Lyapunov vectors are localized. The localization lengths of Lyapunov vectors are proportional to inverse Lyapunov exponents. Moreover, we investigate the transport behavior of the system by considering the "spin-spin" and current-current correlation functions. Our results indicate that the overall transport behavior remains unchanged in the thermodynamic limit in the presence of local perturbation.

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Characterizing the mixed eigenstates in kicked top model through the out-of-time-order correlator

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Generic systems are usually associated with a mixed classical phase space. The question of the properties of the eigenstates for these systems remains less known, although it plays a key role for understanding several important quantum phenomena, such as thermalization, scarring, tunneling, and delocalization. In this work, by employing the kicked top model, we perform a detailed investigation of the dynamical signatures of the mixed eigenstates via the out-of-time-order correlator (OTOC). We show how the types of the eigenstates get reflected in the short- and long-time behaviors of the OTOC and conjecture that the dynamics of the OTOC can be used as an indicator of the mixed eigenstates. Our findings further confirm the usefulness of the OTOC for studying quantum complex systems and also provide more insights into the characters of the mixed eigenstates.

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Ostwald ripening - an unfinished story

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Ostwald ripening [1] may be important in atmospheric science [2] because it provides a non-collisional route for the growth of water droplets in clouds: small droplets evaporate preferentially due to Laplace pressure, and larger droplets grow by condensation.

The process was the subject of a subtle analysis in a classic paper by Lifshitz and Slezov [3] (see [4] for an exposition in English), which is widely accepted as a correct theory for growth in the long-time limit. In this talk I shall explain the Ostwald ripening process and the Lifshitz-Slezov theory, before discussing some recent work on this problem.

I present numerical results showing that there is an essential instability in the process, and give a theoretical explanation. This instability does not have a large effect on the long-time limit of the droplet growth, but it does imply that the Lifshitz-Slezov theory is not exact. Ostwald ripening remains a significant open problem.

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Out-of-time-ordered correlators from a combinatorical approach

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Inspired by the dyck (lattice) path in combinatorics, we introduce a new method in studying out-of-time order correlator of infinite high temperature. The time evolution of a local operator in quantum many-body systems can be viewed as walks in lattices. Each lattice represents one possible configuration in operator spaces and the weight of each walk is related to the Hamiltonian. The complexity of lattices of operators relies heavily on both the Hamiltonians and the operators. We have studied some easy operator lattices, and derived the exact OTOC expressions. With the help of knowledge and skills developed in combinatorics, such as generating functions and Lagrange inversion, we are able to derive OTOC expressions for some complex Hamiltonians. The combinatorial approach can also be readily applied to studying two-point correlation functions in many-body systems.

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Localization in non-Gaussian random band matrices

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We found that the average entropy localization length of non-Gaussian random band matrices follows the same scaling law as in Gaussian cases, provided the distribution of each matrix element has a zero mean (independent and identically distributed) and exhibits exponential decay, irrespective of whether it is symmetrical or not. Additionally, the spectral statistics conform to the Brody distribution with a consistent Brody parameter, as a function of the scaling parameter b^2/N, where b is the bandwidth and N the matrix size.

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Črne luknje v letu 2024

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V letu 2024 sem bil udeležen pri dveh odkritjih črnih lukenj in njihovih lastnosti. Kot prvo je moja magistrska študentka Ema Mlinar v ugledni reviji MNRAS objavila raziskavo, v kateri sva pokazala, da masa črnih lukenj zvezdnih mas ne raste s širjenjem vesolja. To presenetljivo trditev so v Astrophysical Journal Letters leta 2023 objavili Farrah in sodelavci. Emina raziskava trditev s precejšnjo gotovostjo ovrže. Za raziskavo je Ema Mlinar dobila tudi letošnjo plaketo Uroša Seljaka.

Aprila 2024 smo v okviru kolaboracije Gaia objavili odkritje najmasivnejše črne luknje, ki je zanesljivo nastala iz zvezde, doslej. Odkritje močno podpira domnevo, da so črne luknje z masami nekaj deset Sončevih mas, kakršne opazijo pri merjenju gravitacijskih valov ob njihovem zlivanju, nastale iz zelo masivnih prvih generacij zvezd v mladem vesolju.

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Black Holes in 2024

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Recently, I have been contributing to two discoveries related to black holes. In the first study my magister student Ema Mlinar published her results about possible cosmological growth of masses of black holes. This unusual claim has been published in 2023 in the Astrophysical Journal Letters by Farrah et al. We have shown that this is excluded with a high degree of confidence for stellar mass black holes. Her results, which were published in the Monthly Notices of the Royal Astronomical Society, got a recognition Uroš Seljak award in 2024.

In April I contributed to the discovery of the most massive black hole for which we can confirm that it is of stellar origin. The discovery lends a strong support to the explanation that black holes with several ten Solar masses, which have been detected through gravitational wave emission during their merger events, actually formed from the first generations of very massive stars in the young universe.

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