Izboljšave migracije za raziskave z georadarjem

ANDREJA ABINA

MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
andreja.abina@mps.si • www.mps.si

UROŠ PUC

MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
uros.puc@mps.si • www.mps.si

ALEKSANDER ZIDANŠEK

IJS - Institut Jožef Stefan, Jamova 39, Ljubljana
MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
FNM - Fakulteta za naravoslovje in matematiko Univerze v Mariboru, Koroška 160, Maribor
aleksander.zidansek@ijs.si • www.ijs.si

Georadar [1] je geofizikalna metoda, ki z radarskimi pulzi preiskuje prostor in predmete pod površino. Omogoča iskanje skritih predmetov [2] ter izdelavo približnih slik z metodo, ki se imenuje migracija. Migracija se uporablja kot ključna metoda procesiranja radarskih podatkov z namenom izobljšanja resolucije in razvijanja prostorsko realističnih slik podpovršinskih objektov. Naloga migracije je pretvorba izmerjenih časovnih signalov v prostorsko informacijo, s čimer se popravi pozicija in amplituda posnetih signalov na osnovi iskanja idealne difrakcijske hiperbole [3]. V tem prispevku bomo predstavili nekaj izboljšav Kirchhoffove in Stoltove migracijske metode, ki prispevajo h kakovosti slike detektiranih objektov.

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Improvements of migration for georadar investigations

ANDREJA ABINA

Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
andreja.abina@mps.si • www.mps.si

UROŠ PUC

Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
uros.puc@mps.si • www.mps.si

ALEKSANDER ZIDANŠEK

J. Stefan Institute, Jamova cesta 39, Ljubljana, Slovenia
Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška 160, Maribor, Slovenia
aleksander.zidansek@ijs.si • www.ijs.si

Georadar (GPR) [1] is a geophysical method, which uses radar pulses to investigate places and objects underground. It can find location of hidden objects [2] and create an approximated image. The final method in GPR for data processing, called migration, improves resolution and develops spatially realistic images of the subsurface objects. The purpose of this method is to convert measured time domain radar signal into spatial information. Furthermore, migration tries to correct the position and amplitude of the recorded GPR signals with the aim to find an ideal diffraction hyperbola [3]. Finally, in this contribution we present several improvements of Kirchhoff and Stolt migration methods, which affect the quality of calculated image.

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Fraktalna dimenzija robotsko lasersko kaljenega orodnega jekla

MATEJ BABIČ

EMO-ORODJARNA D.O.O.
Bežigrajska cesta10, SI-3000 Celje, Slovenia
matej.babic@emo-orodjarna.si

Predstavil bom fraktalno strukturo pri robotsko lasersko kaljenem orodnem jeklu. Prav tako bom pokazal eksperimentalne rezultate in analize fraktalnih vzorcev, ki se pojavljajo pri robotsko laserskem kaljenju. Na koncu bom še pokazal fraktalno dimenzijo pri robotsko lasersko kaljenem orodnem jeklu. Robotsko lasersko kaljenje se uporablja v letalski, avtomobilski in vesoljski industriji.

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Fractal dimension of the robotically laser hardening tool steel

MATEJ BABIČ

EMO-ORODJARNA D.O.O.
Bežigrajska cesta10, SI-3000 Celje, Slovenia
matej.babic@emo-orodjarna.si

I will present a fractal structure with a robotic laser hardening tool steel. I also will show the experimental data and the analysis of fractal patterns that occur in robotic laser quenching. In the end I will show a fractal dimension of the robotically laser hardening tool steel. Robotic laser hardening is used in the aerospace, automotive and aerospace industries.

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Vlasov Dynamics and Regularity in Long-Range Systems

ROMAIN BACHELARD

School of applied sciences
University of Nova Gorica, Vipavska 11c, SI-5270 Ajdovščina, Slovenia
bachelard.romain@gmail.com

Long-range interactions are encountered in a wide range of systems, from wave-particle interactions (plasma physics, Free Electron Lasers, Collective Atomic Recoil Laser) to astrophysics and hydrodynamics. They are characterized by a strong coupling of all the bodies (potential in $1/r^a$, with $a < d$ the dimension of the system), and their dynamics exhibits a special feature: These systems get trapped in out-of-equilibrium regimes over very long times, diverging with the number of bodies in interaction. These dynamics are called "Quasi-Stationnary States" (QSS).

We first characterize the QSS in the framework of the Hamiltonian Mean-Field model (HMF), composed of N rotators globally coupled through the total magnetization of the system. It can then be shown that when the number of degrees of freedom of the system increases (via the number of particles), the trajectories tend toward periodic and quasi-periodic orbits (presence of invariant tori). Eventually, in $N \to \infty$ limit, the system is described by a Vlasov equation, which is infinite-dimensional, and yet the particles have regular trajectories.

Finally, we show that these results can be generalized to more complex systems such as lattices (existence of a continuum of Vlasov equations) and wave-particle dynamics (emergence of low-dimensional bifurcations).

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Semiempirična teorija porazdelitve razmikov sosednjih nivojev izza BR režima: Modeliranje efektov tunelinarnja in lokalizacije

BENJAMIN BATISTIĆ in MARKO ROBNIK

CAMTP - Center za uporabno matematiko in teoretično fiziko
Univerza v Mariboru, Krekova 2, SI-2000 Maribor, Slovenia
Benjamin.Batistic@gmail.com, Robnik@uni-mb.si
• *www.camtp.uni-mb.si*

Klasična struktura Hamiltonskih sistemov se odraža v statistiki energijskega spektra ustreznega Hamiltonskega operatorja. V tem kontekstu je najpomembnejša statistična mera porazdelitev razmikov med sosednjimi energijskimi nivoji, $P(S)$. Če je klasični sistem integrabilen, je $P(S)$ Poissonova porazdelitev, če je klasični sistem v celoti kaotičen, je $P(S)$ GOE porazdelitev. Za klasične sisteme mešanega tipa, kjer fazni prostor sestavlja tako regularna kot kaotična komponenta, vemo, da je v semiklasični limiti $P(S)$ Berry-Robnikova (BR) porazdelitev. Preden dosežemo semiklasiňo limito, in s tem zadostimo pogojem BR teorije, moramo upoštevati efekte lokalizacije lastnih stanj na kaotični komponenti in efekte tuneliranja med kaotično in regularno komponento. Efekt lokalizacije na kaotični komponenti fenomenološko dobro opišemo, če v BR teoriji nadomestimo GOE porazdelitev za kaotične nivoje z Brodyevo porazdelitvijo. Efekt tuneliranja obravnavamo s pomočjo ustreznega modela naključnih matrik. Sklopitve med kaotičnimi in regularnimi nivoji poskušamo modelirati na dva načina: kot blok matriko (T-model), kjer sklapljamo samo regularne in kaotične nivoje ali kot razpršeno matriko (S-model), kjer sklapljamo naključne pare nivojev. Na osnovi primerjave obeh modelov s konkretnimi fizikalnimi podatki ugotovimo, da zgolj S-model dobro opiše efekte tuneliranja.

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Semiempirical theory of level spacing distribution beyond the BR regime: Modeling the localization ant the tunneling effects.

BENJAMIN BATISTIĆ and MARKO ROBNIK

CAMTP - Center for Applied Mathematics and Theoretical Physics
University of Maribor, Krekova 2, SI-2000 Maribor, Slovenia
Benjamin.Batistic@gmail.com, Robnik@uni-mb.si
• *www.camtp.uni-mb.si*

Classical structure of the Hamiltonian system reflects in the statistical properties of the energy spectrum of the corresponding quantum Hamiltonian operator. In this context the nearest energy level spacing distribution, $P(S)$, is the most important statistical measure. If the classical system is integrable, the corresponding $P(S)$ is the Poisson distribution, while if the classical system is fully chaotic, the corresponding $P(S)$ is the GOE distribution. For the classical systems of the mixed type, where the phase space is the composition of the regular and the chaotic component, we know, that in the semiclassical limit $P(S)$ is the Berry-Robnik (BR) distribution. Before we reach the semiclassical limit and thus satisfy the condition of the BR theory, we have to consider the effects of the localization on the chaotic component and the effects of the tunneling between the chaotic and regular component. The effects of the localization on the chaotic component are well described by replacing the GOE distribution with the Brody distribution in the BR theory. The tunneling effects can be described by the proper random matrix model. We propose two random matrix models: block matrix (T-model) where we couple regular and chaotic levels and sparsed matrix (S-model) where we couple random pairs of levels. By comparison of models with the numerical data of the physical system we conclude that only the S-model successfully describes the tunneling effects.

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Thermodynamics with abstract composition rules

TAMAS S. BIRO

KFKI Research Institute for Particle and Nuclear Physics
Hungarian Academy of Science, Konkoly-Thege M.ut 29-33, H-1121 Budapest, Hungary
tsbiro@rmki.kfki.hu • www.rmki.kfki.hu/t̃sbiro

I review how the validity of the basic laws of thermodynamics can be extended to non-additive composition formulas of classically extensive quantities, like energy, volume, particle number and entropy. Based on a general definition of the thermodynamical limit as a large number of repetitions of the micro-composition perscription, I show that effective composition rules for such repeatedly composed systems are associative, can be uniquely mapped to the addition and are zeroth-law compatible. Based on this construction the canonical distribution, the entropy formula and classical mesoscopic approaches, like e.g. the Boltzmann equation, all generalize in a natural manner. A few examples for composition laws used in physics will be shown and in particular recent experimental high energy particle spectra are reviewed in the framework of this generalized canonical statistics.

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Elektronsko fononska sklopitev vodi do znižanja kinetične energije bipolarona v $t-J$-Holsteinovem modelu

JANEZ BONČA

Fakulteta za matematiko in fiziko, Univerza v Ljubljani, SI-1000 Ljubljana, Slovenija
J. Stefan Institu, SI-1000 Ljubljana, Slovenija
janez.bonca@ijs.si • www-f1.ijs.si/~bonca

S pomočjo metode točne diagonalizacije v omejenem funkcijskem prostoru [1-3] smo izračunali kinetično energijo ter efektivno maso polarona in bipolarona v $t-J$-Holsteinovem modelu. Z večanjem elektronsko fononske sklopitve se zmanjšuje kinetična energija bipolarona v primerjavi s kinetično energijo polarona. Ob tem se zmanjša tudi povprečno število fononov v sistemu bipolarona. Posledično se zmanjša tudi efektivna bipolaronska masa [4]. Naši rezultati kažejo na nov mehanizem v sistemih koreliranih elektronov, sklopljenih z mrežnimi prostostnimi stopnjami, vsled katerega pride ob vezavi parov vrzeli do povečane mobilnosti vsled znižanja kinetične energije ter zmanjšanja efektivne mase. Privlačna sklopitev je posledica medsebojnega sodelovanja mrežnih ter magnetnih prostostnih stopenj.

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Gain of the kinetic energy of bipolarons in the t-J-Holstein model based on electron-phonon coupling

JANEZ BONČA

Faculty of Mathematics and Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia
Institut J. Stefan, SI-1000 Ljubljana, Slovenia
janez.bonca@ijs.si • www-f1.ijs.si/∼bonca

Using exact diagonalization within a limited functional space [1-3] we explore the kinetic energy and the effective mass of polaron and bipolaron in the t-J-Holstein model. With increasing electron-phonon coupling bipolaron kinetic energy is lowered in comparison with that of the polaron. This effect is accompanied with "undressing" of bipolaron from lattice degrees of freedom. Consequently, the effective bipolaron mass becomes smaller than the polaron mass [4]. Our results lead to a novel paradigm where in a correlated system, coupled to quantum lattice degrees of freedom, upon pair formation the bipolaron mobility increases due to a lower effective mass as well as due to a detectable gain in bipolaron kinetic energy. The attractive potential for binding of bipolaron appears as a cooperative interplay between magnetic and lattice degrees of freedom.

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Quasi–Stationary Chaotic States in Multidimensional Hamiltonian Systems

TASSOS BOUNTIS

CRANS - Center for Research and Applications of Nonlinear Systems and Department of Mathematics University of Patras, 26500 Patras, Greece

tassos50@otenet.gr • www.math.upatras.gr/∼crans

We study numerically probability density functions (pdfs) of chaotic orbit coordinates, viewed as independent random variables in weakly chaotic regimes of three multi–dimensional Hamiltonian systems: Two Fermi–Pasta–Ulam (FPU–β) oscillator chains with different boundary conditions and number of particles and a microplasma of identical ions confined in a Penning trap and repelled by mutual Coulomb interactions. For the FPU systems, we show that, when chaos is limited within "small size" phase space regions, these pdfs are well approximated, for surprisingly long times (typically up to $t \approx 10^6$), by a q–Gaussian ($1 < q < 3$) distribution and tend to a true Gaussian ($q = 1$) for longer times, as the orbits eventually enter into "large size" chaotic domains of phase space. In the many-particle case, q–Gaussians are seen to be related to the existence of a single chaotic breather, which breaks down at higher energies as equipartition occurs and the pdfs become Gaussian. In the case of the microplasma Hamiltonian, we make use of these q–Gaussian distributions to identify: (a) a low–energy range of "weak chaos", over which the system "melts" and the q–index of the distributions attains a maximum $q \approx 1.8$ returning quickly to the $q = 1$ (Gaussian) value and (b) a wide energy range, over which a "liquid to gas" transition occurs, where q rises again, reaching $q \approx 1.4$ at $E \approx 50$, before returning slowly back to $q = 1$, at higher energies $E > 200$.

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Quantum dynamics on the attosecond scale[1]

JOACHIM BURGDÖRFER [2]

Institute for Theoretical Physics, Vienna University of Technology, Austria

With the advent of sub - femtosecond ultrashort XUV pulss and of phase-stabilized IR pulses with sub-cycle time resolution, novel pathways have been opened up for studying time-resolved electronic quantum dynamics on the attosecond scale. These experiments pose challenges for theory: How do short pulses interact with matter? Which novel information can be extracted from time-resolved specroscopies that cannot be gained from precision experiments in the spectral domain ? In this talk, these issues will be addressed with the help of a few examples. Attosecond streaking allows a direct look at electronic correlations and rearrangement processes. Photoemission from solid surfaces reveal an attosecond time delay between conduction electrons and core electrons and provide time-resolved information on electron transport, plasmon excitation and dissipation. Attosecond pulses allow not only to probe but also to control and manipulate electronic dynamics which we will illustrate for two-electron emission and molecular break-up.

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Aging transition and spatiotemporal dynamics in coupled qualitatively different oscillators

HIROAKI DAIDO

Department of Mathematical Sciences
Graduate School of Engineering
Osaka Prefecture University
Sakai 599-8531, Japan
daido@ms.osakafu-u.ac.jp

Large populations of coupled dissipative oscillators have been one of the most popular targets of research in nonlinear dynamics. It is now well known that such dynamical systems exhibit a variety of curious behaviors which may lead to novel applications, e.g. synchronization and clustering. Such a system is typically supposed to be an ensemble of all *active* oscillators, where "active" means being capable of showing self-sustained activity such as oscillation and chaos. The theme of this talk is to discuss how the dynamics of such a large scale dynamical system may change when it is subjected to an *aging* process in a generalized sense, in which active oscillators are replaced by *inactive* ones. Taking a class of diffusively coupled limit-cycle oscillators as an example, I will show that under some conditions, the aging causes a remarkable transition to quiescence (a steady state) and that such a transition, termed an *aging transition*, possesses several different kinds of features, depending on the coupling strength, the coupling architecture and so forth. Spatiotemporal dynamics of a locally coupled system will also be discussed.

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The three Trojan Problem

RUDOLF DVORAK

Institute for Astronomy, University of Vienna
A-1180, Vienna, Tuerkenschanzstrasse 17
dvorak@astro.univie.ac.at

We treat the problem of three massive bodies in the Trojan configuration. It is well known that in the so-called restricted three-body problem, where two massive bodies (m_1 and m_2) have Keplerian orbits and a third massless body m_3 moves in the gravitational field of the two primaries, there exist the two stable Lagrangian points L_4 and L_5. The equilibrium points form an equilateral triangle with the primary bodies and motion in the vicinity is stable for mass ratios of the primaries above a certain limit. In the Solar system there move thousands of Trojan asteroids close to the Lagrangian points of the Sun-Jupiter system, but also Neptune 'hosts' such asteroids. When the system consists of 4 massive bodies, namely a central much more massive body (we may call it host star) and three less massive bodies (we may call them planets), then there exist a stable configuration up to certain masses for slightly shifted equilibrium points namley 47° instead of 60° in the classical Lagrange configuration. We investigate the stability regions around this equilibrium point for different masses, libration with respect to the primary and slightly smaller and larger semimajor axis.

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Vlakenski mikro-optični senzorji in druge naprave

EDVARD CIBULA, SIMON PEVEC, DENIS ĐONLAGIĆ

Faculty of Electrical Engineering and computer science, University of Maribor
Smetanova 17, SI-2000, Maribor, Slovenia
ddonlagic@uni-mb.si

Podan je pregled tehnologije za mikro-obdelavo optičnega vlakna, ki ne vključuje litografskega maskiranja. Tehnologija temelji na vnosu germanijevega dioksida v silicijevo steklo, kar spremeni hitrost jedkanja stekla v primeru, da takšno steklo izpostavimo sredstvu za jedkanje kot npr. HF ali pufrani HF. Vnos germanijeva dioksida v silicijevo steklo tako omogoča nadzorovano izdelavo mikro-votlin in podobnih struktur na vrhu optičnega vlakna. Kadar takšna mikro-obdelana vlakna nadalje zvarimo, lahko izdelamo vrsto različnih mikro-optične naprave znotraj ali na vrhu optičnega vlakna. Predstavljena tehnologija mikro-obdelave je bila uporabljena za načrtovanje in praktično izdelavo mikro-kolimatorjev, vlakenskih zrcal, tlačnih in temperaturnih senzorjev ter senzorjev raztezkov.

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All-fiber micro-optic sensors and devices

EDVARD CIBULA, SIMON PEVEC, DENIS ĐONLAGIĆ

Faculty of Electrical Engineering and computer science, University of Maribor
Smetanova 17, SI-2000, Maribor, Slovenia
ddonlagic@uni-mb.si

An overview of a maskless optical fiber micromachining technology is presented. When germania is doped into silica glass, the etching rate of silica changes when exposed to the etching medium such as HF or buffered HF. Introduction of germania in silica glass thus allows for controlled formation of micro cavities and similar structures at the tip of optical fiber. When such micro-machined fibers are further combined or spliced, various micro-optic devices can be created inside or at the tip of an optical fiber. The presented micromachining technology was applied to design and practical formation of micro-collimators, in-fiber mirrors, pressure, strain, and temperature sensors.

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Turbulence transition in shear flows: what can we learn from pipe flow?

BRUNO ECKHARDT

Fachbereich Physik and LOEWE Zentrum Synmikro
Philipps-Universität Marburg, Germany
3TU, TU Delft, Netherlands
bruno.eckhardt@physik.uni-marburg.de

According to textbook wisdom, flow down a pipe becomes turbulent near a Reynolds number of about 2000. This simple statement misses many subtleties of the transition: the absence of a linear stability of the laminar flow, the sensitive dependence on perturbations that sometimes succeed and sometimes fail to induce turbulence and the unexpected observation that the turbulent state, once achieved, is not persistent but can decay. All these observations are compatible with the formation of a strange saddle in the state space of the system. I will focus on three aspects: on the appearance of 3-d coherent states, on the information contained in lifetime statistics and on results on the boundary between laminar and turbulent regions. The properties observed in pipe flow suggest a generic structuring of state space in flows where turbulent and laminar flow coexist.

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Top kvark in fizika hadronskih trkalnikov

SVJETLANA FAJFER

Fakulteta za matematiko in fiziko, Univerza v Ljubljani in Institut J. Stefan
Jadranska 19, SI-1000 Ljubljana, Slovenia
svjetlana.fajfer@ijs.si

Med fundamentalnimi fermioni ima top kvark največjo maso. Kljub dejstvu, da je bil top kvark odkrit v devetdesetih letih prejšnjega stoletja pri poskusih na visokih energijah v hadronskemu trkalniku, je njegova vloga zelo pomembna tudi pri nizkih energijah. V fiziki Standardnega modela so njegove lastnosti zelo dobro raziskane. Predstavila bom rezultate naših raziskav o vplivu korekcij močne interakcije na procese razpada top kvarka. Velike energije hadronskega trkalnika LHC omogočajo zelo natančen študij njegovih lastosti v produkciji in razpadih na katere lahko vpliva tudi fizika izven Standardnega modela. Navedla bom lastnosti razširitve Standardnega modela, v kateri nastopajo skalarni mezon in posledice njihovega obstoja na fiziko top kvarka.

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Top quark and hadronic colliders physics

SVJETLANA FAJFER

physics Dept., University of Ljubljana and J. Stefan Institute
Jadranska 19, SI-1000 Ljubljana, Slovenia
svjetlana.fajfer@ijs.si

The top quark is the heaviest among fundamental fermions. Although top quark has been discovered at high energies in the experiments on hadronic collider in nineties, its role in the low - energy physics has been very important. Within Standard model top quark properties have been carefully investigated. I will present our results on the strong interaction effects in the top quark decay. Very high energies at large hadron collider enable very precise study of its properties in the single and double production as well as in decays, which might be modified by the physics beyond standard model. I plan to discuss basic properties of the physics beyond Standard model containing colored scalar mesons, which existence might affect top quark physics.

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Pogoji za integrabilnost s homogenimi nelinearnostmi pete stopnje

BRIGITA FERČEC

CAMTP - Center za uporabno matematiko in teoretično fiziko
Univerza v Mariboru, Krekova 2, SI-2000 Maribor, Slovenia
brigita.fercec@gmail.com • www.camtp.uni-mb.si

Problem integrabilnosti sistemov diferencialnih enačb je eden izmed osrednjih problemov v teoriji navadnih diferencialnih enačb. Čeprav je integrabilnost redek pojav in splošen sistem ni integrabilen, so integrabilni sistemi pomembni v študiji različnih matematičnih modelov, ker motnje integrabilnih sistemov pogosto kažejo bogato sliko bifurkacij.
Obravnavamo problem integrabilnosti za sistem

$$\begin{aligned} \dot{x} &= x - a_{40}x^5 - a_{31}x^4y - a_{22}x^3y^2 - a_{13}x^2y^3 - a_{04}xy^4 - a_{-15}y^5, \\ \dot{y} &= -y + b_{5,-1}x^5 + b_{40}x^4y + b_{31}x^3y^2 + b_{22}x^2y^3 + b_{13}xy^4 + b_{04}y^5, \end{aligned} \tag{1}$$

kjer so x, y, a_{ij}, b_{ji} kompleksne spremenljivke. Izkaže se, da so računi, ki so vključeni k določitvi nujnih pogojev za integrabilnost za polno družino (1), tako težki, da ne morejo biti izvedeni niti z uporabo močnih računalnikov in sistemov moderne algebre. Tako je smiselno obravnavati nekatere poddružine sistema (1). Nedavno so bili dobljeni pogoji za integrabilnost za poddružino (1) z $a_{-15} = b_{5,-1} = 0$, ki se imenuje Lotka-Volterra sistem in jih najdemo v [1]. Mi smo obravnavali integrabilnost sistema (1) z $a_{-15}b_{5,-1} \neq 0$ in našli nujne pogoje za obstoj lokalnega prvega integrala oblike $\Psi(x, y) = xy + h.o.t.$ za sledeče štiri poddružine tega sistema

$$(C_1)\ a_{40} = b_{04} = 0, \quad (C_2)\ a_{31} = b_{13} = 0, \quad (C_3)\ a_{13} = b_{31} = 0, \quad (C_4)\ a_{04} = b_{40} = 0.$$

Za večino primerov smo pokazali, da so dobljeni pogoji tudi zadostni za obstoj lokalnega prvega integrala.

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Integrability of some systems with homogeneous quintic nonlinearities

BRIGITA FERČEC

CAMTP - Center for Applied Mathematics and Theoretical Physics
University of Maribor, Krekova 2, SI-2000 Maribor, Slovenia
brigita.fercec@gmail.com • www.camtp.uni-mb.si

The problem of integrability of systems of differential equations is one of central problems in the theory of ODE's. Although integrability is a rare phenomenon and a generic system is not integrable, integrable systems are important in studying various mathematical models, since often perturbations of integrable systems exhibit rich picture of bifurcations.
We consider the problem of integrability for the system

$$\begin{aligned} \dot{x} &= x - a_{40}x^5 - a_{31}x^4y - a_{22}x^3y^2 - a_{13}x^2y^3 - a_{04}xy^4 - a_{-15}y^5, \\ \dot{y} &= -y + b_{5,-1}x^5 + b_{40}x^4y + b_{31}x^3y^2 + b_{22}x^2y^3 + b_{13}xy^4 + b_{04}y^5, \end{aligned} \tag{2}$$

where x, y, a_{ij}, b_{ji} are complex variables. It turns out that the computations involved in the determination of the necessary conditions of integrability for the full family (2) are so heavy that they cannot be completed even using powerful computers and modern algebra systems. Thus, it is reasonable to study some subfamilies of system (2). Recently, the integrability conditions for the subfamily of (2), with $a_{-15} = b_{5,-1} = 0$, called Lotka-Volterra system, have been obtained in [1]. We study the integrability of system (2) with $a_{-15}b_{5,-1} \neq 0$ and we found necessary conditions for existence of the local first integral of the form $\Psi(x, y) = xy + h.o.t.$ for the following four subfamilies of this system

$$(C_1)\ a_{40} = b_{04} = 0, \quad (C_2)\ a_{31} = b_{13} = 0, \quad (C_3)\ a_{13} = b_{31} = 0, \quad (C_4)\ a_{04} = b_{40} = 0.$$

For the most cases we show that the obtained conditions are also sufficient conditions for the existence of the local first integral.

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Nonlinear Waves: the Fermi-Pasta-Ulam Problem of Equipartition, and The Fate of Anderson Localization

SERGEJ FLACH

Max Planck Institute for the Physics of Complex Systems
Nöthnitzer Str. 38, 01187 Dresden, Germany
flach@pks.mpg.de • www.pks.mpg.de

I will discuss and review two interrelated problems of statistical mechanics of nonlinear waves. The first case is the Fermi-Pasta-Ulam problem, where no equipartition was observed originally, despite the assumed nonintegrability of the underlying model. We will go through the history of this old problem, see some recent results, and discuss the Kolmogorov-Arnold-Moser results in the light of localization in action space. Then we turn to the second case - the dynamics of nonlinear waves in disordered media. Skipping nonlinearity (i.e. wave-wave interactions) the problem is reduced to the celebrated case of P. W. Anderson, for which he showed that, under certain mild conditions, one-dimensional systems will show Anderson localization. I will show recent results on the propagation of nonlinear waves through such disordered media, and discuss the fate of Anderson localization in the presence of wave-wave interactions.

In-flight dissipation as a mechanism to suppress Fermi acceleration.

DIEGO F. M. OLIVEIRA and MARKO ROBNIK

CAMTP - Center for Applied Mathematics and Theoretical Physics
University of Maribor, Krekova 2, SI-2000 Maribor, Slovenia
diegofregolente@gmail.com ; robnik@uni-mb.si

Dissipative systems have attracted much attention during the development of nonlinear dynamics since they can be used to explain different physical phenomena in different fields of science. The billiard models are often considered since they can be easily described mathematically and can be realized experimentally in many different ways. From the mathematical point of view, a billiard is defined by a connected region $Q \subset R^D$, with boundary $\partial Q \subset R^{D-1}$ which separates Q from its complement. If the system has a time-dependent boundary, $\partial Q = \partial Q(t)$, it can exchange energy with the particle upon collisions. In such a case it is possible to investigate the phenomenon called Fermi acceleration, i.e., the unlimited energy growth. According to Loskutov-Ryabov-Akinshin (LRA) conjecture [1], the existence of a chaotic component in the phase space with static boundary is a sufficient condition to observe Fermi acceleration when a time dependent perturbation is introduced. Results that corroborate the validity of this conjecture include the time dependent oval billiard, stadium billiard and Lorentz gas. However, it is still not clear what happens in integrable systems when we introduce time dependent perturbation on the boundary. Recently, it was shown even that a specific time dependent perturbation in the boundary of an elliptical billiard (integrable) leads to the unlimited energy growth [2]. The separatrix gives place to a chaotic layer and the particles can experience unlimited energy growth while diffusing in the chaotic layer. Since the phenomenon of Fermi acceleration is present in this model our next step is to introduce dissipation into the system. For one and two dimensional billiard problems that show unlimited energy growth, it has been shown that the introduction of dissipation via inelastic collisions is a sufficient condition to break down the phenomenon of Fermi acceleration. We assume that the particles are immersed in a fluid, and the dissipative drag force is considered to be proportional to the square of the particle's velocity. In our approach, we consider a two-dimensional time dependent elliptical billiard close to the transition conservative-to-dissipative case. Our results allow us to confirm that when in-flight dissipation (due to a drag force) is introduced into the model the unlimited energy growth is suppressed. In both, conservative as well as dissipative cases, we describe the behaviour of the average velocity using scaling formalism [3].

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The ultimate range of thermal convection: Multiple scaling? Multiple states?

SIEGFRIED GROSSMANN

Fachbereich Physik
Philipps-Universität Marburg, Renthof 6, D-35032 Marburg, BRD
grossmann@physik.uni-marburg.de

Based on joint work with Detlef Lohse

In the last decade turbulent thermal convection has been studied very intensively. Precise measurements of the heat flow through Rayleigh-Bénard cells together with theory have confirmed our physical picture that the effective heat transport, measured by the Nusselt number Nu, is determined by the properties of (a) the still quasi-laminar, Prandtl type boundary layers, from which thermal plumes detach, and (b) from the turbulent fluctuations in the bulk; see [1,2,3,4,5]. The different scaling of the thermal and kinetic boundary layer thicknesses with the Rayleigh number Ra lead to the breaking of a pure geometric scaling, i. e., there is no simple power law $Nu \propto Ra^{\beta}$. Instead, the exponent $\beta(Ra, Pr)$ depends on Ra and the Prandtl number Pr, which both may vary over a wide range.

A long standing mystery is the heat transport for extremely strong thermal driving Ra beyond about 10^{14}, known as the ultimate range of thermal convection. Conflicting experiments [6,7] stimulated many ideas to better understand Rayleigh-Bénard convection and its various aspects. Quite recently new measurements in the ultimate range with a new apparatus, the so called Goettingen U-Boot, have been performed and still are under way in order to resolve the puzzles of this range. Preliminary results [8,9,10] shed new and quite surprising light on the ultimate regime. They add to the richness of phenomena rather than resolving the existing puzzles.

These new data prompted us to reanalyze the ultimate range theoretically, cf. [11]. Our main ideas and results are presented in this talk. Apparently the ultimate range shows structures, depending again on the various properties of the boundary layers. While the velocity boundary layer has become turbulent beyond some 10^{14}, extending thus with its log-law profile over the whole RB-cell, the thermal boundary layer may still be laminar, the heat transport either being plume or bulk fluctuation dominated, until it also becomes turbulent with its own log-law profile. These distinct states enjoy different scaling behaviors $Nu \propto Ra^{\beta}$ with typically $\beta = 0.14, 0.22$, and 0.38. If the system even switches between these states, also other exponents between these values may occur. – Such features have been found in model systems like the Lorenz equations, cf. [12] and are known as multiple states of highly nonlinear systems.

After a short *status quo* overview the talk aims at contributing to the present discussion of the recently detected surprising properties of the ultimate range of thermal convection and to offer a possible physical understanding.

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Randomness in classical deterministic motion

FRITZ HAAKE

Fakultät für Physik
Universität Duisburg-Essen
fritz.haake@uni-due.de
www.theo.physik.uni-due.de/tp/ags/haake_dir/haake.html

Certain billiards on surfaces of constant negative curvature, known as (pseudo-) arithmetic, are fully chaotic but have periodic orbits highly degenerate in length. Depending on the boundary conditions for the quantum wave functions, the energy spectra either have uncorrelated levels usually associated with classical integrability (arithmetic case) or conform to the "universal" Wigner-Dyson type (pseudo-arithmetic case) although the classical dynamics in both cases is the same. The Maslov indices of orbits within multiplets of degenerate length either yield equal phases for the respective Feynman amplitudes (and thus Poissonian level statistics) or give rise to amplitudes with uncorrelated phases (leading to Wigner-Dyson level correlations). The recent semiclassical explanation of spectral universality in quantum chaos is thus extended to the latter case of pseudo-arithmetical billiards.

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Določeni novi napredki v klasični teoriji termoelektričnosti

MARTIN HORVAT

Oddelek za fiziko, Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, 1000 Ljubljana
martin.horvat@fmf.uni-lj.si • *http://chaos.fmf.uni-lj.si*

Z uporabo termoelektričnih efektov lahko izgradnimo majhne in tihe toplotne stroje in hladilnike, vendar je njihov izkoristek majhen v primerjavi z ostalimi stroji s te vrste. S ciljem izboljšati njihov izkoristek, smo študirali učinkovitost klasično-mehanskih sistemov. Ugotovljeno je bilo, da se tipična mera izkoristka ZT lahko v določenih primerih bistveno izboljša. Prav tako je bil predstavljen preprost klasični model toplotnega stroja/hladilnika, ki obljublja, da bo podal nekaj splošnih smernic za načrtovanje teh strojev v prihodnje. Model je sestavljen iz toplega in hladnega termokemičnega rezervoarja povezanih z vodniki, ki jih modeliramo kot klasične deterministične sipalce. V posebnih primerih kanalov lahko pridobimo analitične rezultate in pokažemo, da je izkoristek blizu Carnotovega izkoristka za ceno nizke proizvodnje moči v primeru toplotnega stroja oz. pretoka toplote v primeru hladilnika.

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Some recent developments in classical theory of thermoelectricity

MARTIN HORVAT

Department of physics, Faculty of mathematics and physics
University of Ljubljana, Jadranska 19, SI-1000 Slovenia
martin.horvat@fmf.uni-lj.si • http://chaos.fmf.uni-lj.si

Using the thermoelectric effect we can build very small and noiseless heat engines and refrigerators, but their efficiency is small compared to other machines of these kind. With the goal to improve their efficiency we have studied the performance of classical-mechanical systems. It was found that the common merit of efficiency ZT can be improved in certain cases. Additionally, a simple classical model of a heat engine/refrigerator is introduced, which promises to give some general guidelines for future designs. It is composed of a hotter and colder thermochemical bath connected via conductors modelled as classical deterministic scatterers (e.g. Poincaré maps). In specific cases of channels analytical results can be obtained showing that a near to Carnot efficiency is reachable at the price of a low-power output in the case of the heat engine or low heat transport in the case of refrigerator.

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Zlomitev elektrošibke simetrije brez Higgsovega bozona na LHC

JERNEJ F. KAMENIK

Institut Jožef Stefan
Jamova 39, SI-1000 Ljubljana, Slovenia
jernej.kamenik@ijs.si • www-f1.ijs.si/∼kamenik/

Ena ali več težkih resonanc s spinom 1 lahko nadomesti Higgsov bozon in ohrani perturbativno unitarnost standardnega modela do energij dosegljivih na velikem hadronskem trkalniku (LHC). Vendar morajo hkrati zadostiti tudi elektrošibkim preciznim testom. Predstavil bom napovedi generičnih modelov elektrošibke zlomitve brez lahkega Higgsovega bozona za LHC, če zahtevamo njihovo unitarnost do energij nekaj TeV ter ujemanje z elektrošibkimi preciznimi meritvami. V nedavni analizi smo pokazali, da lahko vsem zahtevam zadosti že scenarij z eno samo vektorsko resonanco mase $m_V \lesssim 0.5$ TeV. V prisotnosti dodatne aksialne resonance se meja na m_V povzpe do 1 TeV, aksialna masa pa tipično leži v območju $1.2 m_V \lesssim m_A \lesssim 1.4 m_V$. Potem bom obravnaval produkcijo tipa Drell-Yan vektorskih in aksialno vektorskih stanj na hadronskih trkalnikih. Osredotočil se bom na končna stanja $\ell^+\ell^-$, WZ ter stanja s tremi umeritvenimi bozoni. V primeru $\ell^+\ell^-$ obstoječe meritve na pospeševalniku Tevatron že omejujejo parametrični prostor takšnih modelov. Natančneje, izključujejo scenarij z osamljeno vektorsko resonanco. Po drugi strani so končna stanja z dvema ali tremi umeritvenimi bozoni (še posebno WZ, WWZ in WZZ) zelo zanimiva za LHC. V primeru relativno lahke aksialne resonance bi namreč njihove meritve lahko pomembno osvetlile vlogo resonanc s spinom 1 v elektrošibkih preciznih testih.

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ElectroWeak symmetry breaking without a Higgs boson at the LHC

JERNEJ F. KAMENIK

Institut Jožef Stefan
Jamova 39, SI-1000 Ljubljana, Slovenia
jernej.kamenik@ijs.si • www-f1.ijs.si/∼kamenik/

One or more heavy spin-1 fields may in principle replace the Higgs boson in keeping perturbative unitarity up to a few TeV while at the same time account for the electroweak precision tests. I shall discuss the viability of generic Higgsless models at low energies when compliance with electroweak precision observables and unitarity constraints at the LHC energy scale are imposed. Our recent analysis shows that a consistent description can be achieved even with a single light vector state $m_V \lesssim 0.5$ TeV. Introducing an additional axial-vector state, m_V is still predicted to be light (below 1 TeV) while typical values of m_A span over the window $1.2 m_V \lesssim m_A \lesssim 1.4 m_V$. Then I shall consider the Drell-Yan production of heavy vector and axial-vector states in generic Higgsless models at hadron colliders. I will focus in particular on the $\ell^+\ell^-$, WZ, and three SM gauge boson final states. In the $\ell^+\ell^-$ case, present Tevatron data already restricts the allowed parameter space of these models. In particular, it disfavors the single vector resonance scenario. The two and three gauge boson final states (especially WZ, WWZ, and WZZ) are particularly interesting in view of the LHC, especially for light axial-vector masses, and could shed more light on the role of spin-1 resonances in the electroweak precision tests.

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Prvi rezultati eksperimenta ATLAS na LHC

BORUT PAUL KERŠEVAN

Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenia
Institut "Jožef Stefan"
Jamova cesta 39, SI-1000 Ljubljana, Slovenia
borut.kersevan@ijs.si • *www-f9.ijs.si*

Od pomladi leta 2010 je eksperiment ATLAS na Velikem hadronskem trkalniku zabeležil velik nabor podatkov ob trkih protonov pri težiščni energiji 7 TeV. V letu 2011 se bo ta nabor podatkov povečal še za nekaj redov velikosti. Predstavil bom prve rezultate meritev napovedi Standardnega modela v tem novem energijskem območju in pokazal odlično delovanje detektorja ATLAS. Predstavljeni bodo prvi primeri analiz onkraj Standardnega modela in priprave na nadaljnje raziskave.

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First results of the ATLAS Experiment at LHC

BORUT PAUL KERŠEVAN

Faculty of Mathematics and Physics
University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
"Jožef Stefan" Institute
Jamova cesta 39, SI-1000 Ljubljana, Slovenia
borut.kersevan@ijs.si • www-f9.ijs.si

Since Spring 2010 the ATLAS experiment at the Large Hadron Collider has recorded a substantial statistics of proton-proton collision data at a centre-of-mass energy of 7 TeV and a further increase by orders of magnitude is expected by the end of the year 2011. In this talk first results on Standard Model physics obtained in this new energy domain will be presented, demonstrating the outstanding performance of the ATLAS detector. First examples of BSM search results will be given and the preparation for a wider range of searches will be discussed.

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Kompleksne mreže v fraktalnem prostoru

KOUSUKE YAKUBO[1] in DEAN KOROŠAK[2]

[1] *Department of Applied Physics, Hokkaido University, Sapporo 060-8628, Japan*
[2] *University of Maribor, Slomškov trg 15, SI-2000 Maribor, Slovenia*
dean.korosak@uni-mb.si

Neenakomerna razporeditev vozlov v prostoru ima velikokrat pomemben vpliv na strukturo skalno neodvisnih mrež vpetih v prostor. V tem prispevku bomo predstavili model geografskih mrež, kjer so vozli vpeti v fraktalni prostor in kjer lahko spreminjamo jakost prostorske vpetosti. Kadar so uteži vozlov takšnih mrež potenčno porazdeljene, so mreže skalno neodvisno urejene. Eksponent porazdelitve povezav v primeru močne prostorske vpetosti pada z naraščajočo fraktalno dimenzijo prostora in je v primeru šibke prostorske vpetosti enak $\gamma = 2$. Pokazali bomo, da je takšna odvisnost posledica prehoda iz nekompaktne v kompaktno ureditev mreže ter da ta prehod spremlja sprememba v učinkovitosti mreže.

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Complex networks on a fractal space

KOUSUKE YAKUBO[1] and DEAN KOROŠAK[2]

[1] *Department of Applied Physics, Hokkaido University, Sapporo 060-8628, Japan*
[2] *University of Maribor, Slomškov trg 15, SI-2000 Maribor, Slovenia*
dean.korosak@uni-mb.si

The impact of inhomogeneous arrangement of nodes in space on network organization cannot be neglected in most of real-world scale-free networks. Here, we propose a model for a geographical network with nodes embedded in a fractal space in which we can tune the network heterogeneity by varying the strength of the spatial embedding. When the nodes in such networks have power-law distributed intrinsic weights, the networks are scale-free with the degree distribution exponent decreasing with increasing fractal dimension if the spatial embedding is strong enough, while the weakly embedded networks are still scale-free but the degree exponent is equal to $\gamma = 2$ regardless of the fractal dimension. We show that this phenomenon is related to the transition from a non-compact to compact phase of the network and that this transition accompanies a drastic change of the network efficiency.

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Long-term behaviour of logical circuits under the influence of randomness

ANDREAS LEONHARDT

Fakultät für Mathematik
Technische Universität München
Boltzmannstrasse 3, 85747 Garching, Germany
a_leo@mytum.de

Logical gates are the very basis for our today's digital computing as they realise basic Boolean operations. Such gates are designed in a way that they do (hopefully) not depend on random influences. From a theoretical point of view it is, however, interesting to study the case where randomness is applied to such a gate. Now, clocked gates can be used to build arbitrary circuits. Under certain model assumptions these circuits will – once initialised – evolve by their own. This evolution can be described by a discrete, stochastic dynamical system. I shall give a brief introduction to the modelling I used. For circuits satisfying certain conditions I shall also give an easy description of their behaviour if evolution time tends to infinity.

Scaling with system size of the Lyapunov exponents for the Hamiltonian Mean Field model

THANOS MANOS

School of applied sciences
UUniversity of Nova Gorica, Vipavska 11c, SI-5270, Ajdovščina, Slovenia
thanos.manos@gmail.com

The Hamiltonian Mean Field (HMF) model is a prototype for systems with long-range interactions. It describes the motion of N particles moving on a ring, coupled through an infinite-range potential. The model has a second order phase transition at the energy density $U_c = 3/4$ and its dynamics is exactly described by the Vlasov equation in the $N \to \infty$ limit. Its chaotic properties have been investigated in the past, but the determination of the scaling with N of the Lyapunov Spectrum (LS) of the model remains a challenging open problem. We here show that the $N^{-1/3}$ scaling of the Maximal Lyapunov Exponent (MLE), found in previous numerical and analytical studies, extends to the full LS; not only, scaling is "precocious" for the LS, meaning that it becomes manifest for a much smaller number of particles than the one needed to check the scaling for the MLE. Besides that, the $N^{-1/3}$ scaling appears to be valid not only for $U > U_c$, as suggested by theoretical approaches based on a random matrix approximation, but also below a threshold energy $U_t \approx 0.2$. Using a recently proposed method (GALI) devised to rapidly check the chaotic or regular nature of an orbit, we find that U_t is also the energy at which a sharp transition from *weak* to *strong* chaos is present in the phase-space of the model. Around this energy the phase of the vector order parameter of the model becomes strongly time dependent, inducing a significant untrapping of particles from a nonlinear resonance.

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Fotonika na osnovi mehke snovi

IGOR MUŠEVIČ

Institut J. Stefan , Jamova 39, SI-1000, Ljubljana, Slovenija
Fakulteta za matematiko in fiziko, Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenija
igor.musevic@ijs.si • *http://www.softmatter.si/*

Nematski koloidi so disperzije trdnih ali tekočih delcev v nematskem tekočem kristalu. Kažejo nenavadne lastnosti samourejanja v robustne kristalne strukture in superstrukture, kjer so vezavne energije nekaj 1.000 kT na delec mikrometerske velikosti [1]. Zaradi izjemne mehanske stabilnosti na zunanje motnje, so ti materiali izjemno zanimivi za uporabo v fotoniki. Nedavno smo pokazali, da obstaja soroden razred materialov, ki jih tvorijo disperzije tekočekristalnih kapljic mikrometerskih dimenzij v izotropni tekočini [2]. Tekočekristalna kapljica v izotropni tekočini predstavlja optični mikroresonator, če je lomni količnik kapljice večji od tistega zunaj nje. Svetloba, ki nastane v kapljici, ostane v njej ujeta zaradi totalnega odboja na meji z zunanjo tekočino. Lastne frekvence elektromagnetnega polja v nematskih mikroresonatorjih je mogoče učinkovito spreminjati z zunanjim električnim poljem, obseg uglaševanja pa je stokrat večji kot v trdni snovi. Razpravljal bom o idejah in strategijah uporabe samoorganizacijskih in optičnih lastnosti mehke snovi, ki lahko vodijo do novih principov uravnavanja in generiranja toka svetlobe po mehki snovi.

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Soft Matter Photonics

IGOR MUŠEVIČ

J. Stefan Institute, Jamova 39, SI-1000, Ljubljana, Slovenia
Faculty of Mathematics and Physics, University of Ljubljana,
Jadranska 19, SI-1000 Ljubljana, Slovenia
igor.musevic@ijs.si • http://www.softmatter.si/

Nematic colloids are fascinating materials showing unusual ability to assemble into robust colloidal crystalline structures and superstructures with binding energies exceeding several 1.000 kT per micrometer size particles [1]. This makes them very robust against external perturbation and therefore potentially interesting for technological applications in photonics. Another class of photonic micro-objects has recently been demonstrated, based on dispersions of micrometer-diameter nematic droplets in an immiscible carrier fluid [2]. Having the index of refraction higher than the carrier liquid, the nematic droplet is an optical microresonator, where the light could be trapped and is circulating inside the droplet due to the total internal reflection at the surface. Nematic optical microresonators are superior to the solid-state microresonators, because the tuning range of their resonant frequencies is nearly two orders of magnitude larger. This promises applications in optical microdevices, where the flow of light could be controlled by soft-matter microoptical devices. Ideas and strategies are discuss, how liquid crystalline-based micooptic devices could be assembled or even self-assembled using mechanisms of nematic colloidal assembly. We discuss advantages and disadvantages of this soft-matter approach compared to today's main-stream hard-matter approach.

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A class of time-dependent anharmonic oscillators and their symmetries

GEORGIOS PAPAMIKOS

CAMTP - Center for Applied Mathematics and Theoretical Physics
University of Maribor, Krekova 2, SI-2000 Maribor, Slovenia
geopap1983@gmail.com

Some group theoretic methods for integrating differential equations due to S. Lie and E. Noether are introduced and then applied to a class of time-dependent nonlinear second order differential equations.

In particular, in the first part of this talk some basic concepts will be briefly introduced; namely: continuous groups of transformations and their infinitesimal generators, the concept of a symmetry of a differential equation, simple methods of finding those symmetries (using Lie's algorithm) and how to use them (how to reduce the order of the equation by one, or two in the case of Noether symmetries for equations derived from a variational principle) [1,2,3].

In the second part, Lie's method will be applied to a class of time-dependent, nonlinear oscillators with cubic nonlinearity [4]. A classification of different cases with respect to their Lie point symmetries will be presented and the corresponding reductions of the order of each equation will be given. In some of these cases a second reduction, i.e. integration, is possible due to the special character of the symmetry, namely to preserve also the action integral (that is to be of Noether type). In such cases explicit exact analytic solutions of the underlying systems are given.

This analysis was motivated by the studies of the adiabatic invariants and of the statistical properties of time dependent Hamiltonian systems, the linear and nonlinear oscillators, and finds application in this context, see [5] and references therein.

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Symmetries in low-energy hadron physics

WILLIBALD PLESSAS

Theoretical Physics, Institute of Physics
University of Graz, Universitätsplatz 5, A-8010 Graz, Austria
plessas@uni-graz.at • http://physik.uni-graz.at/itp/

Hadrons (mesons and baryons) constitute most of the visible matter in the universe and interact by strong forces. The latter are described within field theory by quantum chromodynamics (QCD). The corresponding Lagrangian connects the fermionic matter fields (i.e. quarks) with the bosonic force fields (i.e. gluons) and exhibits, in the three-flavor case, a-priori a chiral symmetry $SU(3)_{\mathrm{left}} \times SU(3)_{\mathrm{right}}$. For low-energy hadrons this symmetry gets spontaneously broken and a residual $SU(3)$ symmetry remains. The transition from the chiral to the chirally broken phase is essentially not understood till now, but is manifested as an experimental fact. In the talk I will emphasize that approaches to QCD for hadrons at low energies should essentially observe the symmetries left from spontaneous breaking of chiral symmetry as well as the Lorentz symmetry of special relativity. The former is $SU(3)$, notebaly implying the existence of Goldstone bosons, and the latter is encoded in the Poincaré invariance of the theory. In particular, I will demonstrate that a relativistic quark model respecting these symmetries succeeds in a comprehensive description of baryon properties known from spectroscopy, the electromagnetic as well as weak structures, and elastic low-energy reaction processes.

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Neobičajne transportne lastnosti železovih pniktidov

PETER PRELOVŠEK

Fakulteta za matematiko in fiziko, Univerza v Ljubljani
Institut Jožef Stefan, Ljubljana
peter.prelovsek@ijs.si

Spojine na osnovi železa in pniktidov so v zadnjih dveh letih v središču raziskav znotraj fizike trdnih snovi. Predvsem je razlog v visokih temperaturah prehoda v superprevodno stanje, ki so poleg kupratov najvišje doslej. Poleg tega imajo te snovi vrsto nenavadnih lastnosti, npr. bližino magnetnim nestabilnostim in nekonvencionalno naravo superprevodnega stanja, kar je zelo podobno fiziki kupratov, kljub očitnim razlikam v elektronski strukturi obeh familij supertprevodnikov. V predavanju sem bom posvetil zlasti transportnim lastnostim v normalnem kovinskem stanju, ki odstopajo od običajnih Fermijevih tekočin. Predstavil bom fenomenološko teorijo, osnovano na modelu dveh pasov, ki ju povezuje spinsko posredovana interakcija. Pokazal bom, da so anomalne temperaturne odvisnosti in velike vrednosti upornosti, termonapetosti in Hallove konstante posledica močne sklopitve s spinskimi fluktuacijami in majhnih Fermijevih energij relevantnih elektronskih pasov.

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Anomalous Transport Properties of Iron Pnictides

PETER PRELOVŠEK

Faculty of Mathematics and Physics, University of Ljubljana
Jozef Stefan Institute, Ljubljana
peter.prelovsek@ijs.si

Iron pnictide compounds are in last two years one of the most investigated materials within the solid state community, predominantly since they show besides cuprates the superconductivity at highest temperatures. Moreover, they reveal several properties, in particular the vicinity to the magnetic instability and an unconventional pairing symmetry, similar to cuprates although the electronic structures are rather different. In the talk I will concentrate on normal state transport properties which are also quite far from the usual Fermi-liquid framework. I will present a phenomenological theory of quasiparticle scattering and transport relaxation in iron pnictides based on a simplified two-band model with the spin-fluctuation-induced interband coupling. It is shown that the anomalous temperature dependence and large values of normal-state resistivity, thermopower and Hall constant can be interpreted as the consequence of strong coupling to spin fluctuations and low Fermi energies of relevant electron bands.

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Nekaj točno rešljivih modelov transporta v kvantnih mnogo-delčnih verigah daleč od ravnovesja

TOMAŽ PROSEN

Fakulteta za matematiko in fiziko - Oddelek za fiziko
Univerza v Ljubljani
Jadranska 19, SI-1000 Ljubljana, Slovenija
tomaz.prosen@fmf.uni-lj.si • *chaos.fmf.uni-lj.si*

Predstavil bom pristop k reševanju odprtih mnogo-delčnih kvantnih sistemov, ki temelji na Fockovih prostorih gostotnih operatorjev. Takšna obravnava je še posebej primerna za študij Lindbladovih ali Redfieldovih master enačb za kvadratne fermionske ali bozonske verige in omogoči izračun nekaterih eksplicitnih rezultatov o kvantnem transportu in neravnovesnih kvantnih faznih prehodih. Kot primer bomo obravnavali Heisenbergovo XY verigo spinov 1/2 $[1, 2, 3]$. Pokazal bom tudi kako v nekaterih primerih interagirajočih odprtih kvantnih verig lahko zapišemo ekspliciten izraz za neravnovesno stacionarno stanje, npr. za XX verigo s t.i. "dephasing" šumom [4], fermionsko Hubbardovo verigo, ali za Heisenbergovo XXZ verigo spinov 1/2 [5] za katero znamo analitično reproducirati nedavno numerično opaženo negativno diferencialno prevodnost [6].

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On some exactly solvable cases of far from equilibrium transport in many-body quantum chains

TOMAŽ PROSEN

Faculty of Mathematics and Physics - Department of Physics
University of Ljubljana
Jadranska 19, SI-1000 Ljubljana, Slovenia
tomaz.prosen@fmf.uni-lj.si • *chaos.fmf.uni-lj.si*

An approach towards exact solution of many-body open quantum systems based on Fock spaces of density operators shall be reviewed. Such treatment is particularly well suited for studying Lindblad or Redfield master equations of quadratic fermionic or bosonic chains where certain explicit results on heat transport and non-equilibrium phase transitions can be obtained. As an example we outline Heisenber XY spin 1/2 chain [1, 2, 3]. Furthermore, one is able to write down explicit non-equilibrium steady states for some interacting quantum spin chains, such as XX chain with dephasing noise [4], fermionic Hubbard chain, or Heisenberg XXZ spin 1/2 chain [5] for which we analytically reproduce recently numerically observed negative-differential-conductance [6].

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Enodimenzionalni niz anten za georadar

UROŠ PUC

MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
uros.puc@mps.si • www.mps.si

ANDREJA ABINA

MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
andreja.abina@mps.si • www.mps.si

ALEKSANDER ZIDANŠEK

IJS - Institut Jožef Stefan, Jamova 39, Ljubljana
MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
FNM - Fakulteta za naravoslovje in matematiko Univerze v Mariboru, Koroška 160, Maribor
aleksander.zidansek@ijs.si • www.ijs.si

PAVEL CEVC

IJS - Institut Jožef Stefan, Jamova 39, Ljubljana
MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
pavel.cevc@ijs.si • www.ijs.si

Georadar [1] je geofizikalna metoda, ki z radarskimi pulzi preiskuje prostor in predmete pod površino. Omogoča iskanje skritih predmetov [2] ter oceno njihovih materialnih lastnosti, kot je dielektrična konstanta. Najbolj razširjeni so sistemi z monostatsko konfiguracijo oddajne in sprejemne antene [3]. Razvili smo linearno antensko polje, sestavljeno iz niza širokopasovnih georadarskih anten (UWB). Predstavili bomo lastno razvit sistem, s katerim je možno narediti sliko skritih predmetov pod površino in izboljšati resolucijo sistema v prečni smeri. Predstavili bomo nekaj primerov uporabe in nekaj testnih meritev, iz katerih smo ocenili prostorsko ločljivost sistema.

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One-dimensional linear array of antennas for georadar

UROŠ PUC

Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
uros.puc@mps.si • www.mps.si

ANDREJA ABINA

Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
andreja.abina@mps.si • www.mps.si

ALEKSANDER ZIDANŠEK

J. Stefan Institute, Jamova cesta 39, Ljubljana, Slovenia
Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška 160, Maribor, Slovenia
aleksander.zidansek@ijs.si • www.ijs.si

PAVEL CEVC

J. Stefan Institute, Jamova cesta 39, Ljubljana, Slovenia
Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
pavel.cevc@ijs.si • www.ijs.si

Georadar [1] is a geophysical method, which uses radar pulses to investigate places and objects underground. It can find hidden objects [2] and estimate their material properties like a dielectric constant. Nowadays, the most commonly used systems are based on monostatic antenna configuration [3]. However, we developed a linear antenna array consisting of ultra-wideband antennas (UWB). Here we will describe an in-house developed system of linear antenna array for georadar. It allows us to investigate the underground and create images of hidden objects below the surface with increased horizontal resolution. Furthermore, we will present some applications and preliminary measurements for the determination of the spatial resolution of the system.

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Kvantna prepletenost v sistemih sklopljenih elektronov

A. RAMŠAK

Fakulteta za matematiko in fiziko, Univerza v Ljubljani in Institut Jožef Stefan, Ljubljana, Slovenija

Einstein, Podolsky in Rosen so v svojem članku iz leta 1935 zaključili, da je opis realnosti v okviru kvantne mehanike in valovnih funkcij nepopoln. Danes je omenjeni članek sicer najbolj citirano Einsteinovo delo, a kvantne prepletenosti – ki je bila razlog za takratne dvome – ne obravnavamo več kot paradoks, ampak kot enega od gradnikov kvantne obdelave informacije.

V predavanju bomo najprej vpeljali kvantitativno mero prepletenosti delcev, uglašenost (concurrence) in formacijsko prepletenost (entanglement of formation), za sistem sklopljenih elektronov [1,2]. Kot primer bomo prikazali prepletenost elektronov na sistemih kvantnih pik, sklopljenih z okolico (rezervoarjem), kjer se elektroni sklopijo ali v lokalno prepleteno stanje ali pa v stanje, ko so prepleteni z elektroni v rezervoarju (več-delčno Kondovo stanje) [3,4].

Kvantne prepletenosti ne moremo predstaviti in obravnavati v okviru klasične fizike. Lahko pa vizualiziramo kvantno prepletenost v prostoru Bohmovih skritih spremenljivk. Prikazali bomo, kako se da v okviru de Broglie - Bohmove interpretacije kvantne mehanike nazorno predstaviti prepletenost dveh kvantnih bitov.

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Quantum entanglement in interacting electron systems

A. RAMŠAK

Faculty of mathematics and physics, University of Ljubljana and Jožef Stefan Institute, Ljubljana, Slovenia

Einstein, Podolsky and Rosen have in their paper from 1935 concluded that quantum mechanical description of reality as given by wave functions is not complete. Although this article represents Einsteins's most cited publication, is today quantum entanglement – the origin of the debate in 1935 – not considered a paradox, but is an essential resource in emerging field of quantum information processing.

We will present how quantitative measures of entanglement, concurrence and entanglement of formation, can be introduced in fermionic systems [1,2]. As an example the entanglement of interacting electrons in quantum dots coupled to external leads will be considered and the interplay between local entangled state and extended many-body Kondo state will be revealed [3,4].

Quantum entanglement can not be expressed or discussed in the framework of classical physics. However, entangled qubits can be visualized in the space of Bohm hidden variables. It will be shown how in the de Broglie - Bohm interpretation of quantum mechanics entanglement of two interacting qubits can be identified.

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Modeliranje toka nematskega tekočega kristala z metodo Lattice Boltzmann

MIHA RAVNIK

Rudolf Peierls Centre for Theoretical Physics
University of Oxford, 1 Keble Road, Oxford, UK
m.ravnik1@physics.ox.ac.uk

Pomemben element razvoja mikro-fluidnih in laboratorij-na-čipu naprav je nadzor materialnih tokov v mikro-ograjenih geometrijah [1]. V tekočih kristalih je tok sklopljen z deformacijo v orientacijskem redu tekoče kristalnih molekul [2], kar ponuja zanimiv kontrolni mehanizem za tok in nove možne aplikacije, kot na primer samo-sestavljene črpalke v aktivnih tekoče kristalnih koloidih. Zapletenost osnovnih enačb v mikro-fluidnih pojavih tekočih kristalov - posplošena Navier-Stokesova enačba, sklopljena z enačbami nematodinamike - zahteva uporabo učinkovitih in robustnih numeričnih shem.

Tukaj predstavimo profile povratnega toka nematskega tekočega kristala v ograjenih kanalih in votlinah. Delo temelji na fenomenološkem Beris-Edwards modelu, ki ga rešimo s hibridno Lattice Boltzmann metodo. Ta metoda uporablja hkratni eksplicitni diferenčni časovni razvoj orientacijskega reda tekočega kristala in Lattice Boltzmann metodo za materialni tok. Kot vir povratnega toka raziščemo: (i) neravnovesne konfiguracije defektov, ki ustvarijo tok ob relaksaciji v ravnovesno stanje, in (ii) gradiente tlaka, ki ustvarijo stacionarne tokove podobne Poiseuillevemu. Posebej izpostavimo pomen tipov orientacijskega sidranja na površinah kanalov in votlin.

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Modelling Material Flow in Nematic Liquid Crystals Using Lattice Boltzmann Method

MIHA RAVNIK

Rudolf Peierls Centre for Theoretical Physics
University of Oxford, 1 Keble Road, Oxford, UK
m.ravnik1@physics.ox.ac.uk

Controlling material flow in micro-confined geometries is an important element in developing microfluidic and lab-on-the-chip devices [1]. Flow in liquid crystals is coupled to deformation in the orientational order of liquid crystalline molecules [2], which offers a novel steering mechanism for the flow and possibly novel applications, such as self assembled pumps in active liquid crystal colloids. The complexity of governing equations in microfluidic phenomena of liquid crystals -generalized Navier-Stokes equation coupled to equations for nematodynamics- require efficient and robust numerical schemes and solvers.

Here, we present back-flow profiles of nematic liquid crystal in confined channels and cavities. Our study is based on phenomenological Beris-Edwards model, which is solved via hybrid lattice Boltzmann method. The method combines explicit finite difference time evolution for orientational order dynamics and Lattice Boltzmann method for the material flow. As driving sources for back-flow, we explore (i) nonequilibrium configurations of defects that generate flow when relaxing to equilibrium and (ii) local pressure gradients that generate stationary Poiseuille-like flow. The role of surface anchoring types at the walls of channels and cavities is demonstrated.

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Teorija dimenzij in fizika

DUŠAN REPOVŠ

Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenija
dusan.repovs@guest.arnes.si •
http://www.fmf.uni-lj.si/~repovs/index.htm

Predstavil bom matematično teorijo dimenzij in jo pojasnil na nekaterih fizikalnih primerih. Nato si bomo ogledali krajša filma o dimenzijah 3 in 4, s posebnim poudarkom na tem, kako si lahko predstavljamo višjedimenzionalne prostore.

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Dimension theory and physics

DUŠAN REPOVŠ

Faculty of Mathematics and Physics
University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
dusan.repovs@guest.arnes.si •
http://www.fmf.uni-lj.si/∼repovs/index.htm

We shall present mathematical theory of dimensions and illustrate it on some examples from physics. Then we shall present two short movies on dimensions 3 and 4, with special emphasis on how one can view higher-dimensional spaces.

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Stability of relative equilibria in spinning tops

PETER RICHTER

Institute for Theoretical Physics
University of Bremen, Otto Hahn-Allee, D-28359 Bremen, Germany
prichter@uni-bremen.de • *www-nonlinear.physik.uni-bremen.de*

Relative equilibria in rigid body dynamics are stationary solutions of the Euler-Poisson equations and come in four kinds: two of them are steady rotations about the vertical axis, the other two are carrousel type motion where a body-fixed axis revolves around the vertical along a cone. They exist whether or not the system's overall behavior is integrable, and are called Staude solutions because they were first described in [1]. However, it was not before Katok [3] and Tatarinov [4] presented the first bifurcation diagrams that their full complexity became apparent. The set of classical rigid body systems possesses four essential parameters: two moments of inertia and two coordinates for the center of mass. The bewildering variety of different bifurcation diagrams in this four-dimensional parameter set has captured much attention, see [5] for an example. But what about the stability of these relative equilibria? This question has remained largely in the dark, probably because on first sight it looks deceivingly complicated. But as a matter of fact it is surprisingly simple! Grammel's demonstration how the problem reduces to the solution of a quadratic equation [2] seems to have been forgotten. Using this hint it has now become straightforward to add to the bifurcation diagrams the full information about the eigenvalues of linear perturbations of the relative equilibria [6].

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Feroelektrične koloidne mešanice z magnetnimi nanodelci: novi mehki magnetoelektriki

BRIGITA ROŽIČ[1], MARKO JAGODIČ[2], SAŠO GYERGYEK[1], MIHAEL DROFENIK[1], SAMO KRALJ[3], GOJMIR LAHAJNAR[1], ZVONKO JAGLIČIĆ[2], ZDRAVKO KUTNJAK[1]

[1]*Inštitut Jožef Stefan, Jamova 39, 1001 Ljubljana, Slovenija*
[2]*Inštitut za matematiko, fiziko in mehaniko, Jadranska 19, 1000 Ljubljana, Slovenija*
[3]*Fakulteta za naravoslovje in matematiko,Univerza v Mariboru, Koroška cesta 160, Slovenija*
brigita.rozic@ijs.si • *www.ijs.si*

Magnetoelektriki so zelo zanimivi za raziskovalce predvsem zaradi njihovih lastnosti, kot npr. nadzor magnetnih lastnosti preko električnih in obratno, ter zaradi njihove uporabe, npr. pri shranjevanju podatkov [1]. Predstavila bom naše eksperimentalno delo, kjer smo preučevali mešanico magnetnih nanodelcev (ND) in feroelektričnega tekočega kristala (TK) SCE9 v okolici feroelektrične SmC* faze.Dielektrične in toplotne lastnosti omenjenih mešanic smo študirali s pomočjo dielektrične spektroskopije in kalorimetrije visoke ločljivosti. Opazimo podobne efekte kot v primeru aerosilnih delcev [2]. Vpliv električnega polja na magnetno susceptibilnost, ki smo ga izmerili s SQUID susceptometrom, potrjuje obstoj indirektne sklopitve magnetizacije nanodelcev in polarizacije v tekočem kristalu. To potrjuje obstoj magnetoelektričnosti v mehkih kompozitnih materialih kot je mešanica magnetnih ND in feroelektričnega TK.

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Ferroelectric colloidal mixtures with magnetic nanoparticles: new soft magnetoelectrics

BRIGITA ROŽIČ[1], MARKO JAGODIČ[2], SAŠO GYERGYEK[1], MIHAEL DROFENIK[1], SAMO KRALJ[3], GOJMIR LAHAJNAR[1], ZVONKO JAGLIČIĆ[2], ZDRAVKO KUTNJAK[1]

[1]*Jozef Stefan Institute, Jamova 39, 1001 Ljubljana, Slovenia*
[2]*Institute of Mathematics, Physics and Mechanics, Jadranska 19, 1000 Ljubljana, Slovenia*
[3]*Faculty of Natural Science and Mathematics, University of Maribor, Koroška cesta 160, Slovenia*
brigita.rozic@ijs.si • *www.ijs.si*

Magnetoelectrics are recently attracting considerable attention of researchers due to their properties, i.e., in such materials it would be possible to control the magnetic properties via electrical ones, and vice versa and also due to their potencial for applications, for example in information storage industry [1]. I will present our experiments and data analysis obtained on mixture of magnetic nanoparticles (NPs) and the ferroelectric liquid crystal (LC) SCE9 in the vicinity of the ferroelectric smectic C* phase. The impact of the magnetic NPs on the Goldstone and soft mode dielectric response has been determined by the dielectric spectroscopy measurements and the disordering effects on the ferroelectric phase transition have been studied by the high resolution calorimetry. Similar disordering effects were found as in case of the aerosils [2]. Measurements of the impact of the electrical field on the magnetic susceptibility via SQUID susceptometer verified the indirect coupling between the NP's magnetic moments and LC's electrical polarization. This demonstrates that magnetoelectricity can be found in soft composite materials such as mixtures of magnetic NPs and ferroelectric LCs.

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Quantum Difference-Differential Equations

ANDREAS RUFFING

Fakultät für Mathematik
Technische Universität München
Boltzmannstrasse 3, 85747 Garching, Germany
ruffing@ma.tum.de • http://www-m6.ma.tum.de/∼ruffing/

Differential equations which contain the parameter of a scaling process are usually referred to by the name Quantum Difference-Differential Equations. Some of their applications to discrete models of the Schrödinger equation are presented and some of their rich, filigrane und sometimes unexpected analytic structures are revealed.

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Freak waves in the linear regime: A microwave study

HANS-JÜRGEN STÖCKMANN

Fachbereich Physik
Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany
stoeckmann@physik.uni-marburg.de • *www.uni-marburg.de/fb13/forschung/quantenchaos*

Microwave transport experiments have been performed in a quasi-two-dimensional resonator with randomly distributed scatterers, each mimicking an r^{-2} repulsive potential. Analysis of both stationary wave fields and transient transport shows large deviations from Rayleigh's law for the wave height distribution, which can only partially be described by existing multiple-scattering theories. At high frequencies, the flow shows branching structures similar to those observed previously in stationary imaging of electron flow. Semiclassical simulations confirm that caustics in the ray dynamics are likely to be responsible for the observed structures. Particular conspicuous features observed in the stationary patterns are "hot spots" with intensities far beyond those expected in a random wave field. Reinterpreting the flow patterns as ocean waves in the presence of spatially varying currents or depth variations in the sea floor, the branches and hot spots lead to enhanced frequency of freak or rogue wave formation in these regions.

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Tekoči kristali iz ukrivljenih molekul

NATAŠA VAUPOTIČ

Fakulteta za naravoslovje in matematiko
Univerza v Mariboru, Koroška 160, SI-2000 Maribor, Slovenija
Institut "Jožef Stefan"
Jamova 39, SI-1000 Ljubljana, Slovenia
natasa.vaupotic@uni-mb.si • *www.fnm.uni-mb.si*

Odkritje tekočih kristalov, ki jih sestavljajo ukrivljene molekule, je popolnoma spremenilo pogled na urejanje v tekočinskih fazah [1]. Ti tekoči kristali tvorijo faze, ki so večinoma polarne. Poleg tega je ureditev molekularnih dipolov neodvisna od naklona molekul glede na normalo na plast, ki jo tvorijo molekule [2]. Do odkritja tekočih kristalov iz ukrivljenih molekul so imele tekočekristalne faze iz paličastih molekul feroelektrične lastnosti le v primeru, da so osnovni gradniki molekule brez zrcalne simetrije (kiralne molekule). Njihova polarna ureditev je sekundarni ureditveni parameter in je možna le, če je simetrija sistema dovolj nizka (molekule morajo biti nagnjene glede na plast). Ukrivljene molekule pa so v splošnem zrcalno simetrične (nekiralne), pa vendar tvorijo kiralne strukture [3]. Zaradi tega spontanega zloma kiralne simetrije so tekoči kristali iz ukrivljenih molekul še posebej zanimiv modelski sistem. Ker je optična anizotropija v tekočih kristalih iz ukrivljenih molekul zelo velika, pa so ti materiali zelo zanimivi tudi za aplikacije.

Zlom zrcalne simetrije vodi do direktne sklopitve med divergenco polarizacije in povprečnim naklonom molekul. Čeprav je sistem lokalno polaren, divergenca polarizacije omogoča tvorbo makroskopsko nepolarnih sistemov [5,6] in je zato energijsko ugodna. Zaradi sklopitve med divergenco polarizacije in naklonom postanejo homogene, laminarne, plasti molekul nestabilne in se nagubajo (polarizacijsko modulirana in plastno nagubana faza). Če je gubanje premočno, se plasti "zlomijo", deli plasti pa tvorijo stolpce (stolpičaste faze).

Na predavanju bom predstavila lastnosti tekočih kristalov iz ukrivljenih molekul in teoretični model za opis in napoved njihovih lastnosti [7, 8, 9]. Posvetila se bom predvsem dvodimenzionalnim strukturam in njihovemu odzivu na zunanja polja [10].

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Bent-core liquid crystals

NATAŠA VAUPOTIČ

Faculty of Natural Sciences and Mathematics
University of Maribor, Koroška 160, SI-2000 Maribor, Slovenia
Jozef Stefan Institute
Jamova 39, SI-1000 Ljubljana, Slovenia
natasa.vaupotic@uni-mb.si • www.fnm.uni-mb.si

The discovery of bent-core liquid crystals opened a new view on order in liquid-like phases [1]. Bent-core liquid crystals form phases which are in general polar. In addition the ordering of the molecular dipoles (polar order) is independent of the tilt order (molecular tilt with respect to the layer normal) [2]. Before the discovery of bent-core liquid crystals ferroelectricity was observed only in systems formed by chiral rodlike molecules. In these liquid crystals the polar order was a secondary order parameter. Ferroelecricity was possible only if the symmetry of the system was low enough, which required that the molecules tilt with respect to the layer normal. On the other hand, bent-core molecules are in general achiral but they form chiral superstructures [3]. This spontaneous breaking of chiral symmetry makes the bent-core liquid crystals an especially interesting model system. Since bent-core liquid crystals have large optical anisotropy their intensive study is motivated by the application point of view as well.

A direct consequence of the chiral symmetry breaking is coupling between the polarization splay and tilt [4]. Splay of polarization is an escape from the macroscopic polarity of the structure [5, 6]. Coupling between the polarization splay and tilt makes the homogeneously layered structure unstable with respect to polarization modulation and layer undulation (polarization modulated and layer undulated phases). If undulation is too strong, layers break and form stacks (columns) of layer fragments (columnar phases).

I will present the properties of bent-core liquid crystal phases and theoretical modeling of their structure properties [7, 8, 9]. I will focus on the two-dimensional structures and their response to the external fields [10].

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Hibridna metoda za izračun Ruelle-Pollicottovih resonanc

MARTIN HORVAT[1] and GREGOR VEBLE[2,3,4]

[1] *Oddelek za fiziko, Fakulteta za matematiko in fiziko Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenija*
[2] *Univerza v Novi Gorici, Vipavska 13, Rožna Dolina, SI-5000 Nova Gorica, Slovenija*
[3] *Pipistrel d.o.o. Ajdovščina, Goriška c. 50c, Ajdovščina, Slovenija*
[4] *CAMTP - Center za uporabno matematiko in teoretično fiziko, Univerza v Mariboru, Krekova 2, SI-2000 Maribor, Slovenija*
gregor.veble@ung.si

Predstavili bomo numerično metodo za izračun Ruelle-Pollicottovih resonanc v dinamičnih sistemih. Z upoštevanjem korelacij večih opazljivk čez več časovnih korakov sestavimo efektivni grobo zrnati propagator. Metodo primerjamo z običajnimi pristopi za izračun resonanc na primeru perturbirane mačje preslikave in pokažemo, da je numerično učinkovita in robustna.

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A hybrid method for calculation of Ruelle-Pollicott resonances

MARTIN HORVAT[1] and GREGOR VEBLE[2,3,4]

[1] *Department of Physics, Faculty of Mathematics and Physics University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia*
[2] *University of Nova Gorica, Vipavska 13, P.P. 301 Rožna Dolina, SI-5000 Nova Gorica, Slovenia*
[3] *Pipistrel d.o.o. Ajdovščina, Goriška c. 50c, Ajdovščina, Slovenia*
[4] *CAMTP - Center for Applied Mathematics and Theoretical Physics, University of Maribor, Krekova 2, SI-2000 Maribor, Slovenia*
gregor.veble@ung.si

We present a numerical method for calculation of Ruelle-Pollicott resonances of dynamical systems. It constructs an effective coarse-grained propagator by considering the correlations of multiple observables over multiple timesteps. The method is compared to the usual approaches on the example of the perturbed cat map and is shown to be numerically efficient and robust.

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Neravnovesne lastnosti Holsteinovega polarona v konstantnem zunanjem električnem polju

LEV VIDMAR

Institut Jožef Stefan
Jamova 39, SI-1000 Ljubljana, Slovenija
lev.vidmar@ijs.si • *www-f1.ijs.si/∼vidmar*

Opis sistemov daleč stran od ravnovesja predstavlja enega od temeljnih problemov v fiziki. V svojem govoru bom predstavil študijo Holsteinovega polarona [1,2] v eni dimenziji, ki se pod vplivom konstantnega zunanjega električnega polja zapelje stran iz ravnovesja. Z uporabo časovno odvisne Lanczoseve metode [3,4] in z upoštevanjem vseh kvantnih efektov lahko sledimo časovnemu razvoju sistema iz njegovega osnovnega stanja ob $t = 0$, ko vključimo polje, do stacionarnega stanja oziroma stanja s konstantnim tokom.

Pri majhni vrednosti elektronsko-fononske (EF) sklopitve kaže sistem dušene Blochove oscilacije, značilne za energijski pas s prostimi elektroni. Numerični izračun za stacionarno vrednost toka je v tej limiti primerjan s predlaganim analitičnim izrazom za tok, ki je odvisen od EF sklopitve in jakosti polja. Odvisnost stacionarnega toka od polja bo prikazana za različne režime EF sklopitve. V območju močne sklopitve velika energijska reža med osnovnim in prvim vzbujenim stanjem vodi do pojava skoraj idealnih Blochovih oscilacij, ki so posledica gibanja polarona vzdolž polaronskega pasu.

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Non-equilibrium properties of Holstein polaron driven by constant electric field

LEV VIDMAR

Jožef Stefan Institute
Jamova 39, SI-1000 Ljubljana, Slovenia
lev.vidmar@ijs.si • www-f1.ijs.si/∼vidmar

Description of systems far from equilibrium represents one of the fundamental open problems in physics. I will present a study of a Holstein polaron [1,2] in one dimension driven away from equilibrium by a constant electric field along the chain. Using a time-dependent Lanczos method [3,4] and taking fully into account quantum effects, we follow the time-evolution of the system from its ground state as the constant electric field is switched on at $t = 0$, until it reaches a steady state.

At small electron-phonon (EP) coupling the system experiences damped Bloch oscillations characteristic for free electron band. An analytic expression of the steady state current in this limit is proposed in terms of EP coupling and electric field. We investigate the steady state current vs. field dependence for different regimes of EP coupling. In the strong coupling regime a large gap in the spectrum is responsible for observation of nearly perfect Bloch oscillations arising from the polaron motion along the polaron band.

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Recent developments in cosmology – theory and observation

GÜNTER WUNNER

Institute for Theoretical Physics 1
University of Stuttgart, 70550 Stuttgart, Germany
wunner@itp1.uni-stuttgart.de • *www.itp1.uni-stuttgart.de*

What sort of universe do we live in? Observations of supernovae in distant galaxies made by the Hubble space telescope and highly resolved measurements of the cosmic microwave background radiation by the WMAP satellite have brought tramemdous progress over the last decade in answering this question. Comparisons of the observations with the predictions of general relativity suggest that we live in a flat, expanding Friedmann universe, with accelerating expansion rate, in which baryonic matter only contributes 4 per cent to the total energy budget. The rest appears to be comprised of "dark matter" (23 per cent), which can be tracked down indirectly by X-ray observations, and yet unknown "dark energy" (73 per cent), which drives the accelerated expansion of the universe. I shall review these developments, discuss present and future satellite missions for cosmology, and address the question whether or not globally the universe might possess a nontrivial topology.

Sončna energija iz orbite: inovativni koncepti

ALEKSANDER ZIDANŠEK

IJS - Institut Jožef Stefan, Jamova 39, Ljubljana
MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
FNM - Fakulteta za naravoslovje in matematiko Univerze v Mariboru, Koroška 160, Maribor
aleksander.zidansek@ijs.si • www.ijs.si

MILAN AMBROŽIČ

FNM - Fakulteta za naravoslovje in matematiko Univerze v Mariboru, Koroška 160, Maribor
milan.ambrozic@uni-mb.si • www.uni-mb.si

MAJA MILFELNER

FNM - Fakulteta za naravoslovje in matematiko Univerze v Mariboru, Koroška 160, Maribor
maja.martinsek@uni-mb.si • www.uni-mb.si

ROBERT BLINC

IJS - Institut Jožef Stefan, Jamova 39, Ljubljana
MPŠ - Mednarodna podiplomska šola Jožefa Stefana, Jamova 39, Ljubljana
robert.blinc@ijs.si • www.ijs.si

NOAM LIOR

University of Pennsylvania, Department of Mechanical Engineering and Applied Mechanics, Philadelphia, PA, USA
lior@seas.upenn.edu • www.upenn.edu

Glaser je že leta 1968 predlagal izgradnjo sončnih elektrarn v vesolju z namenom proizvodnje elektrike za Zemljo (1). Ideja je sčasoma dozorela in podpisana je že bila prva pogodba v Kaliforniji, ki ima predvideno dobavo električne energije v letu 2016 (2). Opisali bomo nekaj scenarijev ter inovativnih konceptov za znižanje stroškov takšne proizvodnje in dobave elektrike. Najbolj ugodna lega sončnih elektrarn v geostacionarni orbiti, saj lahko od tam dobavljajo elektriko do želene fiksne točke na Zemlji praktično 24 ur na dan. Prva elektrarna bi bila zgrajena na Zemlji in izstreljena v nizko orbito. Nato bi se s proizvedeno energijo dvignila v geostacionarno orbito. Izgradnja nadaljnjih elektrarn bi bila smiselna v robotskih tovarnah na Luni, saj bi to dodatno znižalo stroške, predvsem zaradi lažje izstrelitve elektrarne v geostacionarno orbito. Tako bi lahko že pred polovico tega stoletja njena proizvodna cena padla pod trenutno tržno ceno elektrike (3).

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Solar orbital power: innovative concepts

ALEKSANDER ZIDANŠEK

J. Stefan Institute, Jamova cesta 39, Ljubljana, Slovenia
Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška 160, Maribor, Slovenia
aleksander.zidansek@ijs.si • *www.ijs.si*

MILAN AMBROŽIČ

Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška 160, Maribor, Slovenia
milan.ambrozic@uni-mb.si • *www.uni-mb.si*

MAJA MILFELNER

Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška 160, Maribor, Slovenia
maja.martinsek@uni-mb.si • *www.uni-mb.si*

ROBERT BLINC

J. Stefan Institute, Jamova cesta 39, Ljubljana, Slovenia
Jožef Stefan International Postgraduate School, Jamova cesta 39, Ljubljana, Slovenia
robert.blinc@ijs.si • *www.ijs.si*

NOAM LIOR

University of Pennsylvania, Department of Mechanical Engineering and Applied Mechanics, Philadelphia, PA, USA
lior@seas.upenn.edu • www.upenn.edu

Solar power plants positioned in space for terrestrial electricity use have been proposed by Glaser in 1968 (1). The idea has matured and is close to commercial exploitation with the first contract for orbital electricity signed in California with delivery in 2016 (2). Here we describe several different scenarios and innovative concepts to reduce costs. The best option is to put the power plant into a geostationary orbit where it can provide power to a fixed location on the Earth surface almost 24 hours a day. The first power plant would have to be built on Earth and launched into the low Earth orbit. From there it can be lifted to the geostationary orbit using the power it produces. Further reduction in costs is achieved if the power plants are built in robotic self-replicating factories on the Moon. In this way the cost of orbital electricity could fall below the current market prices of electricity well before the middle of this century (3).

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Morfometrija in struktura naravnih poligonalnih pokritij

PRIMOŽ ZIHERL

Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenija
Institut Jožef Stefan
Jamova 39, SI-1000 Ljubljana, Slovenija
primoz.ziherl@ijs.si

Prerez mnogih prizmatičnih naravnih celičnih struktur, npr. tesnih živalskih in rastlinskih tkiv ter bazaltnih stolpov, je poligonalno pokritje ravnine. Da bi razumeli opaženo visoko stopnjo univerzalnosti teh struktur, analiziramo morfometrične lastnosti nabora eksperimentalnih vzorcev. Raziščemo porazdelitev reducirane ploščine poligonov; to je izoperimetrični kvocient, ki meri podolgovatost poligonov. Dobljene porazdelitve so zelo ostre in zdi se, da pripadajo isti družini. S primerjavo frekvenc razredov poligonov priredimo vsakemu eksperimentalnemu vzorcu modelsko pokritje s poligoni z enakimi ploščinami in enakimi obsegi. Dobro ujemanje nakazuje, da lastnosti naravnih naključnih poligonalnih pokritij v veliki meri določa že mediana reducirane ploščine. Ta sklep pomaga razumeti, odkod univerzalnost opaženih struktur kljub zelo raznorodnemu fizikalnemu izvoru.

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Morphometry and structure of natural polygonal tilings

PRIMOŽ ZIHERL

Faculty of Mathematics and Physics
University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
Jožef Stefan Institute
Jamova 39, SI-1000 Ljubljana, Slovenia
primoz.ziherl@ijs.si

The cross-section of many prismatic natural cellular partitions such as compact animal and plant tissues and basalt columns is a polygonal tiling of a plane. To understand the observed universality of their structure, we analyze the morphometry of a set of living and inanimate planar cellular partitions. We characterize them by the distributions of polygon reduced area, which measures of the elongation of polygons. These distributions are fairly sharp and seem to belong to the same family. By comparing the frequencies of the polygon classes, we map the samples onto model tilings of equal-area, equal-perimeter polygons. We argue that the random two-dimensional patterns can be parametrized by their median reduced area alone. These findings provide a new insight into the origin of the universality of these natural structures, whose mechanics are patently dissimilar.

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Veliki spektroskopski pregledi neba

TOMAŽ ZWITTER

Fakulteta za matematiko in fiziko Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenia
Center odličnosti Vesolje, SPACE-SI, SI-1000 Ljubljana, Slovenia
tomaz.zwitter@uni-lj.si

Naša Galaksija je v vseh pogledih tipična, torej je študij njene strukture in nastanka relevanten tudi za razumevanje vesolja v celoti ("lokalna kozmologija", Freeman & Bland-Hawthorn 2002). To temo je evropska iniciativa Astronet (www.astronet-eu.org) postavila med glavne prioritete astrofizikalnih raziskav v naslednjih dveh desetletjih. Predstavil bom slovensko delo in vključevanje v najpomembnejše tekoče (RAVE, Esina misija Gaia) in bodoče projekte (Hermes, Galactic Chromo Dynamical Survey, Esina misija Plato). Rezultati nam prvič dajejo popolno dinamično in prostorsko informacijo o porazdelitvah zvezd, ki vključuje poznavanje temeljnih parametrov zvezdnih atmosfer, vključno s kemično sestavo. Tako lahko bolje opredelimo lastnosti posameznih galaktičnih komponent in študiramo njihov nastanek. V prihodnosti nam bo podroben študij zastopanosti posameznih kemičnih elementov omogočil vpogled v nastajanje zvezd v medtem že davno razpadlih zvezdnih kopicah, čemur bi lahko rekli galaktična arheologija.

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Large Spectroscopic Stellar Surveys

TOMAŽ ZWITTER

Fakulteta za matematiko in fiziko Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenia
Center of excellence SPACE-SI, SI-1000 Ljubljana, Slovenia
tomaz.zwitter@uni-lj.si

Our Galaxy appears typical in all respects, so the study of its structure and origins can be relevant also for the understanding of the Universe as a whole ("local cosmology", see Freeman & Bland-Hawthorn 2002). This topic has also been chosen as one of the top priorities in astrophysical research in the next two decades by the european initiative Astronet (www.astronet-eu.org). I will summarize the Slovenian work and contributions to the most important current and forthcoming collaborations (RAVE, Esa's missions Gaia and Plato, projects Hermes and Galactic Chromo Dynamical Survey). For the first time the results allow to obtain a complete dynamical and spatial information on stellar distributions, including the knowledge of the basic parameters of stellar atmospheres and their chemistry. This permits a detailed study of the structure and origin of individual galactic components. In the near future data on detailed chemical abundances will become available. So it will be possible to pinpoint the origin of each star to a particular stellar cluster, even if the cluster has dissapeared long ago. The situation can be described as Galactic archaeology.

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Analitična rešitev skoraj izotropnega XY modela sklopljenega z okolico

BOJAN ŽUNKOVIČ

FMF - Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenia
bojan.zunkovic@fmf.uni-lj.si • *chaos.fmf.uni-lj.si*

Obravnaval bom odprte kvantne sisteme [5,6]. Osredotočil se bom na njihov efektivni opis v Markovski aproksimaciji. Splošno teorijo bom uporabil na pirmeru XY modela, kjer je bil numerično opažen neravnovesni kvantni fazni prehod daleč od ravnovesja [1, 2,3]. V posebnih limitah je možna tudi analitična rešitev predstavljenega problema.

Kot primer bom analitično opisal skoraj izotropni XY model z Lindbladovo dinamiko, kjer lahko eksaktno izračunamo prehod med eksponentno padajočimi korelacijami in korelacijami dolgega dosega. V režimu dolgih korelacij opazimo nov fenomen korelacijskih resonanc, kjer dobimo pri določenih vrednostih parametrov sistema (npr. magnetnega polja) nenavadno velike korelacije.[4].

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Analytic solution of nearly isotropic XY model coupled to the environment

BOJAN ŽUNKOVIČ

FMF - Faculty of mathematics and physics
University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
bojan.zunkovic@fmf.uni-lj.si • *chaos.fmf.uni-lj.si*

Quantum system coupled to the environment will be discussed [5, 6]. In particular the effective Markovian approach for quadratic Hamiltonians will be outlined. The general framework shall be applied to the XY spin 1/2 model, where a non-equilibrium phase transition has been observed numerically [1, 2, 3]. In certain limits even analytical calculations are possible.

As an example we will consider the steady state of a nearly isotropic boundary-driven open XY spin 1/2 chain in the Lindblad formulation, where a non-equilibrium quantum phase transition from exponentially decaying correlations to long-range order can be obtained analytically. In the regime of long-range order a new phenomenon of correlation resonances will be presented, where the correlation response of the system is unusually high for certain discrete values of the external bulk parameter (e.g. magnetic field).

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