CAMTP

Center for Applied Mathematics and Theoretical Physics
Univerza v Mariboru

6. Simpozij fizikov Univerze v Mariboru

Zbornik povzetkov

Hotel Piramida
Maribor, 13., 14. in 15. december 2007

Organizacija simpozija: CAMTP - Center za uporabno matematiko in teoretično fiziko, Univerza v Mariboru

Organizacijski odbor:
prof. dr. Marko Robnik, CAMTP
prof. dr. Dean Korošak, Katedra za aplikativno fiziko, Fakulteta za gradbeništvo in CAMTP

Urednika:
prof. dr. Marko Robnik, CAMTP
prof. dr. Dean Korošak, Katedra za aplikativno fiziko, Fakulteta za gradbeništvo in CAMTP

PREDGOVOR

Naši Simpoziji fizikov Univerze v Mariboru, ali na kratko kar Božični simpoziji, imajo že tradicijo, saj imamo letos že šestega po vrsti. Namen je strokovno druženje slovenskih fizikov, ob prisotnosti ter aktivni udeležbi nekaterih kolegov iz tujine kot častnih vabljenih gostov, pri čemer je lansko srečanje preraslo regionalne okvire in je postalo nacionalno srečanje. Srečanje poteka v okviru dejavnosti CAMTP - Centra za uporabno matematiko in teoretično fiziko, organizatorja pa sva skupaj s Prof.Dr. Deanom Korošakom.

Letos si organizatorji in udeleženci štejemo v čast, da bodo med nami, kot vabljeni predavatelji, nekateri odlični slovenski fiziki vseh generacij, iz vse Slovenije. Poleg tega imamo vrsto zelo uglednih gostov iz tujine, predvsem bi tukaj omenil profesorje: Giulio Casati (Como in Singapur), Rudolf Dvorak (Dunaj), Harald Markum (Dunaj), Willibald Plessas (Graz), Petr Šeba (Praga) in Marijan Šunjić (Zagreb). Bodo pa z nami tudi mlajši raziskovalci n.pr. Dr. Michele Armano (ESA, Nordvijk, Nizozemska) ter Dr. Christoph Lhotka (Dunaj).

Rad bi poudaril, da je naše srečanje posvečeno vsej fiziki, teoretični in eksperimentalni, pa tudi matematični fiziki in uporabni matematiki in vsem drugim temam, za katere je fizika pomembna, ali pa so pomembne za fiziko.

Vsa predavanja so na ravni kolokvijev, se pravi razumljiva za splošnega fizika, in zato še posebej primerna za študente, dodiplomske in podiplomske. Takšnih splošnih srečanj na področju fizike v svetu pravzaprav skorajda ni več, čeprav so po našem prepričanju pomembna za širjenje intelektualnega obzorja vseh fizikov. S to dejavnostjo prispevamo tudi k popularizaciji fizike v naši družbi, na trajen način, in ne le zgolj v okviru leta 2005, ki je bilo svetovno leto fizike. Menimo, da je nujno poskrbeti za večjo popularizacijo naravoslovnih ved v naši družbi, in fizika igra pri tem ključno vlogo.

Vsem dodiplomskim študentom dovoljujemo brezplačno udeležbo na vseh predavanjih, in s tem prispevamo k popularizaciji fizike ter k dodatnemu izobraževanju na tem področju.

Nenazadnje bi rad poudaril, da je naše druženje lahko pomemben prispevek pri samo-organiziranju fizikov znotraj nove Fakultete za naravoslovje in matematiko. Upamo, da bo nova fakulteta bistveno prispevala k povezavi fizikov na Univerzi v Mariboru, v smislu delitve pedagoških ter znanstveno raziskovalnih dejavnosti ter rednega strokovnega druženja v obliki kolokvijev itd.

Prof.Dr. Marko Robnik
— Direktor CAMTP —
— Direktor 6. Simpozija —

Seznam udeležencev 6. Simpozija fizikov Univerze v Mariboru

prof. dr. Iztok Arčon
Univerza v Novi Gorici

dr. Michele Armano
SCI-SA ESTEC - The European Space Agency

doc. dr. Jurij Avsec
FS, Univerza v Mariboru

doc. dr. Borut Bajc
Institut Jožef Stefan

prof. dr. Giulio Casati
Center for nonlinear and complex systems, Universita' della Insubria, Como

prof. dr. Martin Čopic
FMF, Univerza v Ljubljani

Vito Despoja
PMF, Sveučilište u Zagrebu

prof. dr. Rudolf Dvorak
Institute for Astronomy, University of Vienna

prof. dr. Dean Korošak
FG, Univerza v Mariboru

dr. Christoph Lhotka
Institute for Astronomy, University of Vienna

prof. dr. Milan Marčič
FS, Univerza v Mariboru

prof. dr. Harald Markum
Atominstitut, Vienna University of Technology

prof. dr. Matej Pavšič
Institut Jožef Stefan

Iztok Pižorn
FMF, Univerza v Ljubljani

prof. dr. Willibald Plessas
Institute of Physics, University of Graz

doc. dr. Primož Potočnik
FS, Univerza v Ljubljani

prof. dr. Anton Ramšak
FMF, Univerza v Ljubljani

prof. dr. Marko Robnik
CAMTP, Univerza v Mariboru

prof. dr. Valery Romanovski
CAMTP, Univerza v Mariboru

Robert Rozman
FS, Univerza v Ljubljani

Marko Samec
FG, Univerza v Mariboru

prof. dr. Petr Seba
Institute of Physics, Academy of Sciences of the Czech Republic

prof. dr. Marijan Šunjić
PMF, Sveučilište u Zagrebu

Gregor Vidmar
CAMTP, Univerza v Mariboru

dr. Yepeng Xing
CAMTP, Univerza v Mariboru

dr. Marko Žnidarič
FMF, Univerza v Ljubljani

prof. dr. Slobodan Žumer
FMF, Univerza v Ljubljani

Urnik 6. Simpozija fizikov Univerze v Mariboru

Četrtek, 13. december 2007	
Chair	Robnik
09:00-10:00	Dvorak*
10:00-11:00	Šunjić*
11:00-11:30	tea, coffee
11:30-12:30	Ramšak*
12:30-13:15	Pavšič*
13:15-15:15	lunch
Chair	Korošak
15:15-16:15	Robnik*
16:15-16:45	tea, coffee
16:45-17:30	Plessas*
17:30-18:15	Potočnik*
18:15-18:45	Pižorn
20:00-	Conference dinner

*vabljeno predavanje/invited lecture

Urnik 6. Simpozija fizikov Univerze v Mariboru

Petek, 14. december 2007	
Chair	Dvorak
09:00-10:00	Arčon*
10:00-10:45	Lhotka*
10:45-11:00	Marčič
11:00-11:30	tea, coffee
11:30-12:00	Avsec
12:00-13:00	Bajc*
13:00-13:30	Xing
13:30-15:15	lunch
Chair	Pavšič
15:15-16:00	Čopič*
16:00-16:45	Markum*
16:45-17:15	tea, coffee
17:15-18:00	Armano*
18:00-18:45	Romanovski*
19:00-	dinner

*vabljeno predavanje/invited lecture

Urnik 6. Simpozija fizikov Univerze v Mariboru

Sobota, 15. december 2007	
Chair	Bajc
09:00-10:00	Casati 1*
10:00-10:45	Žnidarič*
10:45-11:15	tea, coffee
11:15-12:15	Žumer*
12:15-13:00	Seba*
13:00-13:30	Vidmar
13:30-15:15	lunch
Chair	Plessas
15:15-16:15	Casati 2*
16:15-16:45	tea, coffee
16:45-17:30	Rozman
17:30-19:00	Concluding discussions
19:00-	dinner

*vabljeno predavanje/invited lecture

Nanostrukturne analize snovi z rentgensko absorpcijsko spektroskopijo

IZTOK ARČON

Univerza v Novi Gorici
Vipavska 13, SI-5000 Nova Gorica, Slovenia
iztok.arcon@p-ng.si • www.p-ng.si/arcon/xas

Rentgenski absorpcijski spektroskopski metodi EXAFS (Extended X-ray Absorption Fine Structure) in XANES (X-ray Absorption Near Edge Structure) sta uveljavljeni in široko uporabljeni orodji za določanje atomske oziroma molekularne strukture novih materialov s sinhrotronsko svetobo. Spektri XANES dajejo informacijo o valenčnem stanju in lokalni simetriji preiskovanega atoma, medtem ko je iz spektrov EXAFS mogoče določiti vrsto in število sosedov ter njihovo razdaljo od izbranega atoma, pa tudi njihov statični in termični nered. Metodi sta še posebej uporabni pri analizi snovi brez reda dolgega dosega, to je v primerih neurejenih, amorfnih in nanostrukturnih snovi ter tekočin in molekul v plinih, kjer standardna strukturna analiza z rentgensko difrakcijo odpove. Pri dosedanjih raziskavah smo metodi uspešno uporabili pri razvoju več tehnološko pomembnih materialov, kot so npr. mikroporozni katalizatorji, feroelektrične keramike, zaščitne prevleke, nanostrukturni materiali in nekatere farmakološko pomembne meolekule. V okviru predavanja bo predstavljen predvsem interdisciplinarni značaj te vrste fizikalnih raziskav in možnosti za njihovo uporabo pri iskanju okoljevarstvenih rešitev v primerih onesnaženja okolja s težkimi kovinami ter na področju konservatorstva historičnih rokopisov in pri analizi sodobnih nanostrukturnih materialov. Meritve smo izvedli v sinhrotronskih laboratorijih HASYLAB, DESY v Hamburgu, ESRF v Grenoblu, ELETTRA v Trstu in SLS v Daresburyu.

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[1] I. Arčon, J. Kolar, A. Kodre, D. Hanžel, M. Strlič, *X-ray spectrom.* **36** (2007) 199-205.
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[3] I. Arčon, A. Pastrello, L. Catalano, M. De Nobilli, L. Leita, *Environ. Chem. Lett.* **4** (2006) 191-194.

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Nanostructural analysis with x-ray absorption spectroscopy

IZTOK ARČON

Vipavska 13, SI-5000 Nova Gorica, Slovenia
iztok.arcon@p-ng.si • www.p-ng.si/arcon/xas

X-ray absorption methods EXAFS (Extended X-ray Absorption Fine Structure) and XANES (X-ray Absorption Near Edge Structure) are well established and frequently used tools for characterization of atomic and molecular structure of new materials. XANES spectra provide information on the valence state and local symmetry of the investigated atom, while EXAFS is used to determine number and species of neighbour atoms, their distance from the selected atom and the thermal or structural disorder of their positions. The analysis can be applied to crystalline, nanostructural or amorphous materials, liquids and molecular gases. EXAFS is often the only practical way to study the arrangement of atoms in materials without long range order, where traditional diffraction techniques cannot be used. We have successfully used these two methods for the analysis of several technologically important materials, for example microporous catalysts, ferroelectric ceramics, protective coatings, nanostructured materials and some molecules used in pharmacology. In the lecture an interdisciplinary character of research with these physical methods will be presented. Particular attention will be drawn to applications in the field of environmental research (pollution with heavy metals), preservation of cultural heritage (enhanced degradation of paper in historic manuscripts induced by iron gall inks) and structural analysis of nanomaterilas. We performed all the experiments at synchrotron radiation laboratories (HASYLAB, DESY in Hamburgu, ESRF in Grenoble, ELETTRA in Trieste and SLS in Daresbury).

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The LISA and LISA Pathfinder missions

MICHELE ARMANO

LISA Pathfinder Operation Scientist
SCI-SA ESTEC - The European Space Agency
Keplerlaan, 1 - 2200 AG Noordwijk - The Netherlands
marmano@rssd.esa.int • http://www.esa.int

The Laser Interferometer Space Antenna (LISA) is a joint ESA-NASA mission aiming at detection of gravitational waves (GW). GW are a logical prediction of causality and signal propagation in the frame of General Relativity. Indirect proof of their existence from the Hulse-Taylor binary pulsar was provided, but a direct detection is still missing.

I will introduce GW and show why a couple of masses in free fall can be used as detector via interferometer measurement of their relative acceleration. I will describe LISA apparatus in analogy, and show its ability to detect GW in the low frequency bandwidth, something unachievable on ground due to Newtonian noise barriers.

LISA will be constituted by 3 space-crafts in equilateral triangular constellation with side 5 million kilometres wide, sharing Earth's orbit by trailing with $20''$ delay. Two freely-falling test-masses will be shielded inside each space-craft and will act as mirrors for laser beams. Displacements will thus be measured with an accuracy of 10 picometres.

Ground testing to define feasibility and reduce risks is in progress. LISA relies on technologies never tested before and Earth's noisy environment would affect the test results. Hence a proper off-ground validation is mandatory and foreseen: the LISA Pathfinder, carrying the LISA Test Package (LTP) is on plan by ESA due flight on 2009. The main task of LISA Pathfinder is collecting a noise picture in environmental conditions similar to those of LISA and to test the drag-free techniques mimicking free-fall.

I will describe the LISA Pathfinder mission, mostly concentrating on dynamics, signals and sensitivities. I will introduce noise and cross-talk and show how we

intend to perform the basic measurements on board.

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Uporaba statistične termodinamike v nanotehnologijah

JURIJ AVSEC

Fakulteta za strojništvo
Univerza v Mariboru, Smetanova 17, SI-2000 Maribor, Slovenia
jurij.avsec@uni-mb.si

V predstavljenem članku bomo prikazali nov matematični model za izračun toplotne prevodnosti za nanotekočine. Za izračun toplotne prevodnosti smo uporabili neravnotežno statistično termodinamiko. Posebej smo rešili problem toplotne prevodnosti za trdno in kapljevito snov. Hkrati smo v predstavljen model vkjučili še naslednje pomembne dodatne vplive: A. Vpliv nastanka mejne plasti okoli nanodelcev. Hamilton-Crosserjev (HC) model daje zelo ugodne rezultate za nanodelce, ki so večji od 13 nm, za manjše nanodelce pa eksperimentalni podatki potrjujejo velike napake v HC modelu. HC model za izračun toplotne prevodnosti v nanotekočinah podaja odvisnost od volumskega deleža nanodelcev, ne vsebuje pa informacij o velikosti in obliki nanodelcev. Uporabili smo Yu-Choi-jev model in predpostavko, da se okoli nanodelcev tvori tanka mejna plast. V tem primeru smo korigirali enačbo HC. B. Vpliv hiperboličnega prevoda toplote. Prenos toplote v nanodelcih se prenaša predvsem z elektroni in fononi, odvisno od zgradbe snovi. Makroskopske teorije predpostavljajo v večini primerov difuzijski prenos toplote na osnovi Laplace-jeve enačbe. V nekovinskih nanodelcih se toplota prenaša s pomočjo fononov, v kovinah pa s pomočjo elektronov.. Tako je na primer za baker srednja elektronska prosta pot 350 nm, za aluminij pa 65 nm. Zato se prenos topolote ne more vršiti samo difuzijsko v nanodelcu velikosti okoli 10 nm. Prav zato smo uporabili model razvit na osnovi razširjene nepovračljive termodinamike in vpliva difuzijsko-hiperboličnega prenosa toplote. V tem primeru postane prenos toplote odvisen tudi od Knudsenovega števila. C. Vpliv Brownovega gibanja. Mnogi avtorji v strokovni literature poročajo, da je najpomembnejši vzrok za povečanje toplotne prevodnosti v nanotekočinah, predvsem zaradi Brownovega gibanja, ki povzroča mikro mešanje. V

predstavljenem modelu smo analitično upoštevali tudi vpliv Brownovega gibanja.

Predstavljen članek prikazuje analizo vseh pomembnih vplivov na zelo veliko povečanje toplotne prevodnosti v nanotekočinah. Hkrati so analitični rezultati primerjani z izmerjenimi podatki in kažejo na zelo dobro ujemanje.

The application of statistical thermodynamics in nanotechnology

JURIJ AVSEC

Fakulteta za strojništvo
University of Maribor, Smetanova 17, SI-2000 Maribor, Slovenia
jurij.avsec@uni-mb.si

In the presented paper we have developed the new model for the calculation of thermal conductivity in nanfluids. Our new mathematical model is developed on the basis of nonequilibrium statistical thermodynamics. On the basis of nonequilibrium statistical thermodynamics we have solved the thermal conductivity for solid nanoparticles and for the pure fluid. Additionaly we have taken into account the next phenomena: A. The Influence of nanolayer around nanoparticle. The Hamilton-Crosser (HC) model gives very good results for particles larger than 13 nm. For smaller particles the presented theory gives wrong results with the deviation more than 100B. Hyperbolic heat conduction. Heat transport in nanoparticles is predominantly by electron and crystal vibrations, depends on material. Macroscopic theories assume diffusive heat transport with Laplace equation. In crystalline nanoparticles heat is carried out by phonons, such phonons are created at random, propagate directios, they are scattered by each other. In metals, the heat is primarly carried by electrons, which also exhibit diffusive motion at the macroscopic level. For Cu is lel 350 nm, for Al is lel 65 nm. Due to this reason, electrons cannot diffuse in the 10 nm particles but must move ballistically across the particle. In the presented paper we have developed the new model on the basis of extended irreversible thermodynamics and diffusive-hyperbolic heat conduction. C. Brownian motion. In many authors is postulated that the enhanced thermal conductivity of a nanofluid is mainly, due to Brownian motion which produces micro mixing. Because of the small size of the particles in the fluids, additional energy term can arise from motions induced by stochastic (Brownian) and interparticle forces. Motion of particles cause microconvection that enhances heat transfer:

The presented article shows for the first time in scientific literature the influence of all important effects at the same time and all transport properties are calculated on the basis of statistical thermodynamics. In the presented paper we have made analytical calculations for the nanofluids: water+Al, water+Cu, water+SiO. The analytical results we have compared with experimental data and they show relatively good agreement.

Prediktivna teorija poenotenja

BORUT BAJC

Institut Jožef Stefan
Jamova cesta 39, 1001 Ljubljana, Slovenija
borut.bajc@ijs.si • www.ijs.si

Teorije poenotenja spadajo med glavnimi kandidati za nadgradnjo standardnega modela osnovnih delcev. Glavno motivacijo zanje najdemo med drugim v razlagi kvantizacije naboja, v nevtrinskih masah, ter v poenotenju tako interakcij kot snovi. Predstavil bom enega najenostavnejših a istočasno najbolj prediktivnih modelov te vrste: nesupersimetrični model umeritvene grupe SU(5) z dodatno adjungirano upodobitev fermionov. Pokazal bom, da je napoved takega modela obstoj šibkega tripleta fermionov z maso pod približno 1 TeV, torej v možnem dometu pospeševalnika LHC. V primeru, da je triplet dovolj težek, da ga LHC ne bo našel, model napove relativno hiter razpad protona, kar bi bilo možno zaznati v bližnji bodočnosti. Posebno zanimiva lastnost razpadov teh tripletov je njihova odvisnost od nevtrinskih mas ter mešalnih kotov. Pokazal bom tudi glavne signale za njihovo odkritje v današnjih in bodočih pospeševalnikih.

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A predictive grand unified theory

BORUT BAJC

Jožef Stefan Institute
Jamova cesta 39, 1001 Ljubljana, Slovenia
borut.bajc@ijs.si • www.ijs.si

Grand unified theories are among the main candidates for physics beyond the standard model of elementary particles. The main motivation for them can be found among others in the explanation of the charge quantization, the neutrino masses, and the unification of interactions and matter. I will present one of the simplest and most predictive models of this type: the nonsupersymmetric gauge SU(5) model with an extra fermionic adjoint representation. I will show that the model predicts the existence of a weak fermionic triplet with mass below approximately 1 TeV, which is possibly in the range of LHC. In case its mass is too large for LHC, the model predicts a fast proton decay, to be found in the near future. A particularly interesting feature of these triplets' decays is their connection to neutrino masses and mixing angles. I will show the main experimental signatures for the their discovery in present and future colliders.

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Classical and quantum chaos and understanding and control of heat flow

GIULIO CASATI

Center for nonlinear and complex systems, Universita' della Insubria, Como, Italy
giulio.casati@uninsubria.it

The understanding of the underlying dynamical mechanisms which determines the macroscopic laws of heat conduction is a long standing task of non-equilibrium statistical mechanics. Recent years have witnessed some important progress in this direction even though a satisfactory understanding is, so far, unavailable. For example,after two decades of debates, it is now clear that exponential local instability is not a necessary condition for the validity of Fourier law. A better understanding of the mechanism of heat conduction may also lead to potentially interesting applications based on the possibility to control the heat flow. Indeed, a model of thermal rectifier has been recently proposed in which heat can flow preferentially in one direction. Although this model is far away from a prototype realization, it is based on a mechanism of very general nature and, as such, is suitable of improvement and may eventually lead to real applications. More recently, a different thermal diode model has been proposed in which, even though the underlying physical mechanism is similar to the previous model, there is a new crucial element which allows to improve the efficiency by more than two orders of magnitude. Finally we briefly discuss the possibility to build a thermal transistor. Of particular interest is the problem, almost completely unexplored, of the derivation of Fourier law from quantum dynamics. To this end we discuss heat transport in a model of a quantum interacting spin chain and we provide clear numerical evidence that Fourier law sets in above the transition to quantum chaos.

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Quantum Chaos, Entanglement and Decoherence

GIULIO CASATI

Center for nonlinear and complex systems, Universita' della Insubria, Como, Italy
giulio.casati@uninsubria.it

Decoherence theory has a fundamental interest since it provides explanations for the emergence of classicality in a world governed by the laws of quantum mechanics . It is also relevant for actual implementation of any quantum computation and communication protocol . Here we address the question if a many-body environment can be substituted, without changing the effects on system's dynamics, by a closed deterministic system with a small number of degrees of freedom, yet chaotic. We give a positive answer and in particular we show that the complexity of the environment arises from the chaotic dynamics rather than from the many-body nature.

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Fluktuacije v nehomogenih tekočih kristalih

MARTIN ČOPIČ

Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, Ljubljana, Slovenia
Martin.Copic@fmf.uni-lj.si

Hidrodinamične fluktuacije v sredstvu so določene s tem, da gre njihova frekvenca ali relaksacijska hitrost proti nič za majhne valovne vektorje. So posledica ohranitvenih zakonov in zloma zveznih simetrij, za kar so tekoči kristali lep primer. V homogenem sredstvu so lastni načini fluktuacij ravni valovi, ki so v primeru tekočih kristalov nadkritično dušeni z relaksacijsko hitrostjo, ki jo določa razmerje elastičnih konstant in viskoznosti. Nehomogenosti in meje v sredstvu lahko bistvno spremenijo lastnosti flukutacij. Kot prvi primer bom obavnaval meritve dinamičnega sipanja svetlobe v kvaziperodičnemm kompozitnem sistemu tekočegaa kristala in polimera, kjer je disperzijska zveza orientacijskih flukutacij analogna akustičnim in optičnimm fononskim vejam v kristalih, le da je pojav posledica periodične modulacije viskoznosti. V drugem primeru bom pokazal, kako lastnosti termičnih fluktuacij v omejenih geometrijah omogočajo tudi meritev površinskih inetrakcij tekočih kristalov.

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Fluctuations in inhomogeneous liquid crystals

MARTIN ČOPIČ

Faculty of mathematics and physics
University of Ljubljana, Jadranska 19, Ljubljana, Slovenia
Martin.Copic@fmf.uni-lj.si

Hydrodynamic fluctuations in a medium are the ones where the frequency or relaxation rate approach zero at small wavectors. They are a consequence of conservation laws and breaking of continuous symmetries. Liquid crystals are a good example. In a homogeneous medium the eigenmodes of the fluctuations are plane waves, which are in the case of liquid crystals overdamped with a relaxation rate that is determined by the ratio of elastic constants and visocosity. Inhomogeneities and boundaries in the medium can strongly influence fluctuations. As the first example I will discuss the measurements of dynamic light scattering in a quasi-periodic composite system of liquid crystal and polymer in which the dispresion relation of the orientational fluctuations is analogous to acoustic and optic phonon branches in crystals, with the difference that the phenomenon is due to periodic modulation of the dissipation. As the second example I will show how the properties of thermal fluctuations in restricted geometries enable us to measure surface interactions of liquid crystals.

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Multiplanetary Systems

RUDOLF DVORAK

AstroDynamicsGroup, Institute for Astronomy
University of Vienna, Türkenschanzstr. 17, A-1180 Vienna, Austria
dvorak@astro.univie.ac.at • www.univie.ac.at/adg/

268 extrasolar planets are confirmed by observations by december 2007, where most of them are in single planetary system. But this seems to be just a lack of better techniques to discover them. Recently a fifth planet (!) was discovered in the Extrasolar Planetary System 55 Cancri which is by far the most populated besides our own planetary system. I postulate that there are only very few systems with a single large planet because the formation of planets out from the dust and gas in an early 'Solar' nebulae is a common process. We compare the dynamics of the multiplanetary systems, which sometimes are quite different with respect to their orbits, with our own Solar System.

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Nekhoroshev stability estimates in the Elliptic Restricted Three Body Problem

CHRISTOPH LHOTKA

ADG - Institute for Astronomy
University of Vienna, Tuerkenschanzstrasse 17, A-1180 Vienna, Austria
lhotka@univie.ac.at • www.univie.ac.at/adg/

Exponential stability in nonlinear dynamical systems has been found in particular examples given in literature by Moser (1955) and Littlewood (1959). Contrary to the KAM theorem (Kolmogorov 1954, Arnold 1963, Moser 1962), which asserts stability for all times of those orbits, with initial conditions belonging to a Cantor set of tori of non-zero measure, exponential stability is of much greater interest from the physical point of view, as it can be applied to *all* orbits in open domains of the phase space, whether they lie on an invariant torus or not. The corresponding theorem proven by Nekhoroshev (1977) defines stability regions for a finite time T in both, regular and chaotic domains of the phase space. If the life-time of the physical system is shorter than the stability time derived from the Nekhoroshev estimates of the region, one can definitely say that orbits belonging to this region are stable from the practical point of view. This is the reason, why the Nekhoroshev theorem has to be considered at least as important as the KAM theorem as regards its relevance to the understanding of nonlinear dynamics. The speaker will introduce the audience to the Nekhoroshev theory in short and show one typical application in Celestial Mechanics, where the abstract theorem can reveal physical insights into the system, namely the motion near the 1:1 resonance of the elliptic restricted three body problem (Efthymiopoulos 2005, Lhotka et al 2007).

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Izračun termofizikalnih lastnosti snovi s pomočjo statistične termodinamike

MILAN MARČIČ in JURIJ AVSEC

Univerza v Mariboru
Fakulteta za strojništvo, Smetanova 17, SI-2000 Maribor, Slovenia
milan.marcic@uni-mb.si, jurij.avsec@uni-mb.si • www.fs.uni-mb.si

V inženirski praksi, npr. hlajenju in kriogeniki so procesi izjemnega pomena. Pri konstruiranju hladilnih in grelnih naprav je neobhodno poznavanje termodinamičnih lastnosti hladilnih snovi v enofaznem in dvofaznem področju. V večini primerov se poslužujemo termodinamičnih tabel in diagramov ter različnih empiričnih funkcij dobljenih s pomočjo meritev. V našem primeru smo za izračun termodinamičnih lastnosti uporabili kvantno statistično termodinamiko. V članku je predstavljen matematični model za izračun termodinamičih lastnosti realnega plina. Uporabljena je virialna ekspanzijska teorija z ustreznimi kvantnimi korekcijami. V članku je predstavljen tudi matematični model šibko sklopljenega visoko degeneriranega kvantnega fluida. Izračunali smo termodinamične lastnosti snovi s pomočjo kvantne teorije polja za mnogodelčni sistem, pri čemer smo uporabili metodo končnih temperatur. Uporabljena je bila Feynmann-Dyson-ova perturbacijska teorija. Izračunali smo normalni potencial Maxwell-Boltzmann-ovega sistema s pomočjo temperaturnih Greenovih funkcij in Feynmann-ovih grafov. Primerjava izračunanih in izmerjenih termodinamičnih lastnosti je pokazala dobro skladnost.

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An approach for calculating thermophysical properties with the help of statistical thermodynamics

MILAN MARČIČ and JURIJ AVSEC

University of Maribor
Faculty of Mechanical Engineering, Smetanova 17, SI-2000 Maribor, Slovenia
milan.marcic@uni-mb.si, jurij.avsec@uni-mb.si • www.fs.uni-mb.si

In engineering practice, refrigeration and cryogenics are processes of vital importance. In order to design devices for this field of activity, it is necessary to be familiar with the thermodynamic properties of state in a one-phase and a two-phase environment. In most cases thermodynamic tables and diagrams are used as well as different empirical functions obtained from measurements. In our case, quantum statistical thermodynamics was used to calculate thermodynamic properties of state. The mathematical model for calculation of the thermodynamic properties of state in real gas one-component systems is treated. The virial expansion theory with quantum corrections was used to calculate the thermodynamic functions of state. The paper also deals with the mathematical model of a weakly coupled highly degenerate quantum fluid. We have calculated the thermodynamic properties of state with the help of the quantum field theory (QFT) for many particle systems using finite temperature formalism. We used the Feynmann-Dyson perturbation theory. We developed the expression for the grand potential of normal Maxwell-Boltzmann systems with the help of Green function temperatures and Feynmann's diagrams. The results of the analysis were compared with experimental data and they show good agreement.

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Non-commutative Geometry and Fields on a Lattice

HARALD MARKUM

Atominstitut, Vienna University of Technology
Wiedner Hauptstraße 8-10/141, A-1040 Vienna, Austria
markum@tuwien.ac.at • www.tuwien.ac.at

Theories with noncommutative space-time coordinates represent alternative candidates of grand unified theories. In cooperation with Harald Grosse (Theoretical Physics, Univ. Vienna) and two students, Wolfgang Frisch and Florian Teischinger (VUT), we discuss U(1) gauge theory in 2 dimensions on a lattice with N sites [1]. The mapping to a U(N) one-plaquette model in the sense of Eguchi and Kawai can be used for computer simulations.

We are interested in the formulation and evaluation of topological objects [2]. We performed quantum Monte Carlo simulations and calculated the topological charge for different matrix sizes and several values of the coupling constant. We constructed classical gauge field configurations with large topological charge and used them to initialize quantum simulations. It turned out that the value of the topological charge is decreasing during a Monte Carlo history. Our results show that the topological charge is in general supressed. The situation is similar to lattice QCD where quantum gauge field configurations are topologically trivial and one needs to apply some cooling procedure on the gauge fields to unhide the integer number of the instantons. After an extended introduction, our recent analyses will be presented [3].

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Cliffordova algebra kot pripravno orodje za fiziko

MATEJ PAVŠIČ

Institut Jožef Stefan
Jamova 39, SI-1000 Ljubljana, Slovenia
Matej.Pavsic@ijs.si • www.ijs.si

Cliffordova števila lahko uporabimo za reprezentacijo vektorjev, multivektorjev, in splošnih polivektorjev. So zelo očinkovito orodje za geometrijo in fiziko [1]. Z uporabo geometrijskega računa na osnovi Cliffordove algebre lahko mnoge fizikalne enačbe zapišemo v zgoščeni in elegantni obliki.

Učinkovitost takšnega zgoščenega zapisa znanih enačb pa nas napeljuje na posplošitev, da vse fizikalne količine obravnavamo kot polivektorje [2]. Tako je na primer polivektor gibalne količine

$$P = \mu + p^{\mu}\gamma_{\mu} + S^{\mu\nu}\gamma_{\mu}\gamma_{\nu} + \pi^{\mu}\gamma_5\gamma_{\mu} + m\gamma_5 \tag{1}$$

in polivektor hitrosti $\dot{X} = \dot{\sigma} + \dot{x}^{\mu}\gamma_{\mu} + \dot{\alpha}^{\mu\nu}\gamma_{\mu}\gamma_{\nu} + \dot{\xi}^{\mu}\gamma_5\gamma_{\mu} + \dot{s}\gamma_5$. Pri tem so γ_{μ}, $\mu = 0, 1, 2, 3$ bazni vektorji, ki zadoščajo zvezam $\gamma_{\mu}\cdot\gamma_{\nu} \equiv \frac{1}{2}(\gamma_{\mu}\gamma_{\nu} + \gamma_{\nu}\gamma_{\mu}) = \eta_{\mu\nu}$, medtem ko je $\gamma_5 \equiv \gamma_0\gamma_1\gamma_2\gamma_3$, $\gamma_5^2 = -1$, enotni psevdoskalar. Na podoben način lahko razširimo tudi pojem pozicije, tako da jo opišemo s pomočjo polivektorja. To vodi do pojma tako imenovanega Cliffordovega prostora [3,4], 16-dimenzionalne mnogoterosti, katere tangentni prostor je Cliffordova algebra.

V kvantizirani teoriji predpostavimo, da je stanje reprezentirano s polivektorsko valovno funkijo, ki zadošča enačbi

$$\hat{P}\Phi = 0 \tag{2}$$

kjer je $\hat{P}$ operator. Običajna Diracova enačba je poseben primer Diracove enačbe v Cliffordovem prostoru (2); masa v štirih dimenzijah je dana z lastnimi vrednostmi dodatnih komponent polivektorske gibalne količine $\hat{P}$. Spinorji so posebna vrsta polivektorjev, so namreč elementi levih ali desnih minimalnih idealov Cliffordove algebre, kar je že dolgo znano. Skalarji, vektorji, spinorji, itd., se lahko transformirajo

en v drugega s pomočjo elementov Cliffordove algebre, ki lahko delujejo bodisi z leve, bodisi z desne. To je zanimiva alternativa supersimetriji.

Polje ortonormalnih vektorjev ("vielbein") in povezava v ukrivljenem Cliffordovem prostoru vključuje poleg 4-dimenzionalne gravitacije še druga umeritvena polja. To omogoča združitev osnovnih sil, ne da bi bilo potrebno povečati število dimenzij prostor-časa [5,6].

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Clifford Algebra as a Useful Tool for Physics

MATEJ PAVŠIČ

Jožef Stefan Institute
Jamova 39, SI-1000 Ljubljana, Slovenia
Matej.Pavsic@ijs.si • www.ijs.si

Clifford numbers can be used to represent vectors, multivectors and, in general, polyvectors. They form a very useful tool for geometry and physics [1]. The well known equations of physics can be cast into elegant compact forms by using the geometric calculus based on Clifford Algebra.

Such compact forms suggest a generalization to every physical quantity being a polyvector [2]. For instance, the momentum polyvector is

$$P = \mu + p^{\mu}\gamma_{\mu} + S^{\mu\nu}\gamma_{\mu}\gamma_{\nu} + \pi^{\mu}\gamma_5\gamma_{\mu} + m\gamma_5 \tag{3}$$

and the velocity polyvector is $\dot{X} = \dot{\sigma} + \dot{x}^{\mu}\gamma_{\mu} + \dot{\alpha}^{\mu\nu}\gamma_{\mu}\gamma_{\nu} + \dot{\xi}^{\mu}\gamma_5\gamma_{\mu} + \dot{s}\gamma_5$. Here γ_{μ}, $\mu = 0$, 1, 2, 3 are basis vectors, satisfying $\gamma_{\mu}\cdot\gamma_{\nu} \equiv \frac{1}{2}(\gamma_{\mu}\gamma_{\nu} + \gamma_{\nu}\gamma_{\mu}) = \eta_{\mu\nu}$, and $\gamma_5 \equiv \gamma_0\gamma_1\gamma_2\gamma_3$, $\gamma_5^2 = -1$, is the pseudoscalar unit. Similarly, also position can be extended so to be described as a polyvector. This leads to the concept of so called Clifford space [3,4], a 16-dimensional manifold whose tangent space is Clifford algebra.

In the quantized theory we asume that a state is represented by a polyvector-valued wave function satisfying

$$\hat{P}\Phi = 0 \tag{4}$$

where $\hat{P}$ is operator. The usual Dirac equation is a particular case of the Dirac equation in Clifford space (**??**); mass in four dimensions then comes from the eigenvalues of the extra components of polymomentum $\hat{P}$. Spinors are just special kind of polyvectors, namely the elements of left or right minimal ideals of Clifford Algebra, which is an old observation. Scalars, vectors, spinors, etc., can be transformed into each other by the elements of Clifford Algebra, acting from the left or from the right. This is an interesting alternative to supersymmetry.

In curved Clifford space, connection and vielbein contain, not only the 4-dimensional

gravitational field, but also other gauge fields, thus enabling unification of fundamental forces without increasing the dimensionality of spacetime [5,6].

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Dvodelčni slučajni spinski ensemble in nov tip kvantnega faznega prehoda

I. PIŽORN, T. PROSEN, S. MOSSMANN, in T.H. SELIGMAN

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

V delu obravnavamo lastnosti dvodelčnega slučajnega matričnega ensembla za razločljive spine. Zahtevamo, da je ensemble invarianten na grupo lokalnih transformacij in analiziramo parametrizacijo s parametri grupe in preostalimi parametri, povezanimi s "prepletenim" delom interakcije. Nato se osredotočimo na kvantno spinsko verigo s sklopitvijo med najbližjimi sosedi in iz numeričnih rezultatov opazimo nov tip kvantnega faznega prehoda. Le-ta je povezan z močjo slučajnega zunanjega polja, in sicer z zlomitvijo simetrije na obrat časa pri enodelčnem sklopitvenem členu.

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The two-body random spin ensemble and a new type of quantum phase transition

I. PIŽORN, T. PROSEN, S. MOSSMANN, and T.H. SELIGMAN

Department of Physics, Faculty of Mathematics and Physics
University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
iztok.pizorn@fmf.uni-lj.si • chaos.fiz.uni-lj.si

We study the properties of a two-body random matrix ensemble for distinguishable spins. We require the ensemble to be invariant under the group of local transformations and analyze a parametrization in terms of the group parameters and the remaining parameters associated with the "entangling" part of the interaction. We then specialize to a spin chain with nearest neighbour interactions and numerically find a new type of quantum phase transition related to the strength of a random external field i.e. the time reversal breaking one body interaction term.

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Relativistic few-body problems

WILLIBALD PLESSAS

Theoretical Physics, Institute of Physics
University of Graz, Universitätsplatz 5, A-8010 Graz, Austria
plessas@uni-graz.at

Quantum-mechanical few-body problems have a tradition of almost half a century by now. In both mathematical approaches, solving either a set of differential equations or a set of integral equations, the nonrelativistic quantum theory of few-body problems is well-founded and the dynamical equations can practically be solved with any type of interactions for three- and four-body problems. For some aspects, e.g. for bound states, the calculations may be extended to treating even five and six particles microscopically. Quantum mechanics is made relativistic by imposing Poincaré invariance. Thereby the symmetry requirements of special relativity are incorporated. When dealing with a finite number of degrees of freedom (one, two, three particles etc.), the theory can still be elaborated in a rigorous manner, but one encounters a series of technical and methodological problems. An immediate problem is connected with introducing interactions into the invariant mass operator when passing from a free theory to an interacting one. Furthermore one has to make a choice about the subset of generators of Poincaré transformations affected by interactions, i.e. about working in the instant, front, or point forms of relativistic dynamics. Here I shall discuss viable approaches to relativistic few-body problems, outline their respective advantages and disadvantages, and demonstrate the importance of relativistic effects in case of bound and scattering states of few-quark systems, i.e. in hadron physics. An outlook to challenging problems in the future investigation of relativistic few-body problems will also be given.

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Industrijske aplikacije napovedovanja in spremljanja procesov

PRIMOŽ POTOČNIK, IGOR GRABEC, PETER MUŽIČ, EDVARD GOVEKAR

Laboratorij za sinergetiko
Univerza v Ljubljani, Fakulteta za strojništvo
Aškerčeva 6, SI-1000 Ljubljana, Slovenia
primoz.potocnik@fs.uni-lj.si • www.fs.uni-lj.si/lasin

Predstavljena bosta dva primera v letošnjem letu razvitih industrijskih aplikacij s področja napovedovanja in spremljanja procesov: 1) napovedovanje odjema zemeljskega plina in 2) zaznavanje napak pri industrijski montaži kompresorjev. Pri napovedovanju odjema zemeljskega plina je cilj dnevno napovedovanje predvidenih urnih odjemov za prihodnji dan. Jedro avtomatiziranega sistema napovedovanja je predikcijski model, ki na osnovi vplivnih spremenljivk (vremenska napoved, pretekli odjem, itd.) avtomatično izdela napoved. Za distribucijsko podjetje je takšna napoved kakovostna osnova za kratkoročno optimizacijo delovanja omrežja. Druga predstavljena aplikacija rešuje problematiko v tovarni Danfoss Compressors, d.o.o., kjer pri proizvodnji batnih kompresorjev nastopijo različni problemi med montažo na proizvodni liniji. Predstavljena aplikacija rešuje problem sprotnega zaznavanja montažnih napak, ki lahko povzročijo preobremenitev ali pokanje ojnice kompresorja. Računalniško podprti diagnostični sistem na osnovi meritev sile vtiskovanja omogoča detekcijo nepravilnih vtiskovanj in izločanje poškodovanih kompresorjev iz proizvodnje. Sistem je zasnovan adaptivno in se prilagaja tekoči proizvodnji.

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Industrial forecasting and condition monitoring applications

PRIMOŽ POTOČNIK, IGOR GRABEC, PETER MUŽIČ, EDVARD GOVEKAR

Laboratory of Synergetics
University of Ljubljana, Faculty of Mechanical Engineering
Aškerčeva 6, SI-1000 Ljubljana, Slovenia
primoz.potocnik@fs.uni-lj.si • www.fs.uni-lj.si/lasin

Two forecasting and condition monitoring industrial applications, developed in this year, will be presented: 1) natural gas demand forecasting and 2) condition monitoring of industrial assembling of compressors. The objective of natural gas demand forecasting is daily forecasting of hourly profiles for the next day. The core of an automated forecasting system is a model that produces forecasts automatically based on influential variables (weather forecast, past consumption, etc.). Such forecasts are a basis for short-term optimization of distribution network operation. The second presented application relates to the production in Danfoss Compressors, d.o.o. factory where the production of compressors suffers from assembling problems on the production line. Presented application solves a problem of online condition monitoring of assembling defects that cause overload or crack of the compressor connection rod. Based on the measurement of the imprinting force, the computer based diagnostic system enables detection of irregular imprinting operations and elimination of damaged compressors from the production. The system is designed as adaptive one that automatically accommodates to the current production.

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Kvantna prepletenost v nano sistemih

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 eno od osnovnih sestavin nanoelektronike. V predavanju bomo najprej vpeljali kvantitativno mero prepletenosti delcev [1]. Za primer sklopljenih kvantnih pik in kvantnih žic bomo pokazali, kakšni so izzivi na tem področju za teoretično in eksperimentalno fiziko. Prikazali bomo več predlogov za generacijo popolnoma prepletenih elektronskih parov [2-9] in kako je kvantna prepletenost lahko tudi koristna mera za opis faznih prehodov v fiziki trdnih snovi [10].

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Quantum entanglement in nano 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 nanoelectronics. We will present how a quantitative measure of entanglement can be introduced [1] and review some proposals of perfect entanglers based on coupled quantum dots and wires [2-9]. Quantum entanglement can also be a very efficient precursor of (quantum) phase transitions in correlated solid state systems and as an example some recent results related to entangled qubit pairs on the Shastry-Sutherland lattice will be presented [10].

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Eksaktna analiza adiabatskih invariant v časovno odvisnem harmonskem oscilatorju

MARKO ROBNIK

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

Teorija adiabatskih invariant ima dolgo zgodovino in veliko pomembnih implikacij ter aplikacij v številnih vejah fizike, klasično in kvantno, vendar je redko osnovana na rigoroznih rezultatih. Pričela se je s klasičnim člankom Einsteina v letu 1911, navezujoč na Lorentzov predlog v istem letu. Obravnavamo povsem splošni enodimenzionalni harmonski (linearni) oscilator s časovno odvisno frekvenco, katerega energija v splošnem ni ohranjena, in analiziramo razvoj energije in njene statitične lastnosti, kot je n.pr. porazdelitvena funkcija končnih energij, ki se razvijejo iz začetnega mikrokanoničnega ansambla. Izkaže se, da je ta porazdelitvena funkcija univerzalna, t.j. neodvisna od tega kakšna funkcija časa je frekvenca. Teorija je zanimiva s stališča matematike, saj povezuje elemente iz teorije dinamičnih sistemov, teorije verjetnosti in diskretne matematike, in prikaže teorijo adiabatskih invariant v dinamičnih sistemih v povsem novi luči.

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Exact analysis of the adiabatic invariants in time-dependent harmonic oscillator

MARKO ROBNIK

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

The theory of adiabatic invariants has a long history, and very important implications and applications in many different branches of physics, classically and quantally, but is rarely founded on rigorous results. It began with the classical paper by Einstein in 1911, following a suggestion by Lorentz in the same year. We treat the general one-dimensional harmonic (linear) oscillator with time-dependent frequency whose energy is generally not conserved, and analyse the evolution of the energy and its statistical properties, like the distribution function of the final energies evolved from an initial microcanonical ensemble. This distribution function turns out to be universal, i.e. independent of the nature of the frequency as a function of time. The theory is interesting from the mathematical point of view as it comprises elements of the theory of dynamical systems, the probability theory and discrete mathematics, and sheds new light on the understanding of the adiabatic invariants in dynamical systems.

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Limitni cikli in centri v polinomskih sistemih NDE

VALERIJ ROMANOVSKIJ

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

Preučevali bomo sistem

$$\frac{dx}{dt} = P_n(x, y), \quad \frac{dy}{dt} = Q_n(x, y), \tag{1}$$

kjer sta $P_n(x, y)$ in $Q_n(x, y)$ polinoma stopnje n, x in y sta realni neznani funkciji, in koeficienti polinomov P_n, Q_n so iz nekega prostora $\mathcal{E}$. V primeru, ko ima sistem (1) neizrojen center ali fokus v izhodišču koordinatnega sistema, se pojavi limitni cikl iz izhodišča koordinatnega sistema, če linearizirani sistem (1) spremeni stabilnost. To je dobro znana bifurkacija Andronova-Hopfa. Bifurkacije, ki so odvisne od nelinearnih členov sistema (1) (izrojene Hopfove bifurkacije) so manj proučene, vendar obstaja metoda za študij takih bifurkacij, ki jo je razvil N.N. Bautin.

Cikličnost singularne točke (x_0, y_0) sistema (1) je maksimalno število limitnih ciklov, ki se pojavlja iz singularne točke pri majhnih motnjah. Problem cikličnosti je pomemben del 16. Hilbertovega problema. Prvi korak v preučevanju problema cikličnosti je rešitev t.i. Poincaréjevega problema centra, ki je problem kako najti v $\mathcal{E}$ vse take točke, ki ustrezajo sistemom s centrom v izhodišču koordinatnega sistema (v tem primeru so vse rešitve v okolici izhodišča periodične), in sistemi s fokusom v izhodišču koordinatnega sistema (v tem primeru so rešitve neperiodične in trajektorije so spirale).

Pokazal bom kako lahko metode, ki temeljijo na teoriji baz Gröbnerja, uporabimo za študij problema cikličnosti in Poincaréjevega problema centra. Obravnaval bom tudi medsebojno povezavo zgoraj omenjenih problemov in problema izohronosti nihanj in teorije normalnih form.

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Limit cycles and centers in polynomial systems of ODE's

VALERY G. ROMANOVSKI

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

Consider systems of the form

$$\frac{dx}{dt} = P_n(x, y), \quad \frac{dy}{dt} = Q_n(x, y), \tag{2}$$

where $P_n(x, y), Q_n(x, y)$ are polynomials of degree n, x and y are real unknown functions, and suppose that the coefficients of the polynomials P_n, Q_n are from a parameter space $\mathcal{E}$. In the case when the origin of (2) is a non-degenerate center or focus a limit cycle bifurcates from the origin when the linearized system (2) changes its stability. This is the well-known Andronov-Hopf bifurcation. The limit cycles bifurcations which depend on nonlinear terms of system (2) (sometimes such bifurcations are called degenerate Hopf bifurcations) are much less investigated, but there is a method for their study suggested by N. N. Bautin, which we discuss in the present talk.

We say that the singular point (x_0, y_0) of the system $E_0 \in \mathcal{E}$ *has cyclicity* k if k is the maximal number of limit cycles which appear from (x_0, y_0) after small perturbations. The problem of cyclicity is often called *the local 16th Hilbert problem*. In fact, the first step in the investigation of the cyclicity problem is the solution of the Poincaré center problem. The latter problem is to separate in $\mathcal{E}$ the set of points, which correspond to systems having a center at the origin (in which case all solutions close to the equilibrium one are periodic) from those with a focus (in which case all solutions close to the equilibrium one are non-periodic and their trajectories are spirals).

We apply methods based on the theory of Gröbner bases to the investigation of the Poincaré cyclicity and center-focus problems for system (2). We also discuss

the interrelation of these problems, the problem of isochronicity of oscillations in polynomial systems and the theory of normal forms.

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Model in karakterizacija lasersko tvorjenega plazemskega oblaka

ROBERT ROZMAN, IGOR GRABEC and EDVARD GOVEKAR

Laboratory of Synergetics
University of Ljubljana, Faculty of mechanical engineering,
Aškerčeva 6, SI-1000 Ljubljana, Slovenia
robert.rozman@fs.uni-lj.si • www.fs.uni-lj.si/lasin

Obdelavo materialov z laserskim žarkom visoke intenzitete spremlja pojav izparevanja obsevane snovi in nastanka plazemskega oblaka. Pri določenih pogojih lahko absorpcijski koeficient plazme naraste in poveča absorpcijo energije laserskega žarka v plazemskem oblaku. Posledično se zmanjša del laserske energije, ki doseže površino snovi. Segrevanje snovi se zato znatno zmanjša. Pojav je zelo pomemben pri laserski obdelavi materialov, kjer je pojav poznan pod imenom plazemsko senčenje. Model nastanka lasersko tvorjene plazme [1] opisuje termične pojave pri obsevanju snovi z laserskim žarkom visoke intenzitete. Segrevanje je opisano s toplotno enačbo z upoštevanjem termičnega izparevanja snovi. Tok izparjenega materiala v okolico je opisan z Navier-Stokesovim sistemom enačb, kjer izparjen material in okoliški plin obravnavamo kot idealen ioniziran plin. Absorpcijski koeficient v modelu vključuje tri absorpcijske mehanizme: obratno zavorno sevanje, fotoionizacija in absorpcija svetlobe na majhnih kondenziranih gmotah izparjenega materiala. Model je opisan s sistemom nelinearnih enačb, ki smo ga reševali numerično v dvodimenzionalnem sistemu. Primerjava numeričnih rešitev z eksperimentalnimi meritvami kaže dobro ujemanje. S pomočjo numeričnega modela smo okarakterizirali pojav plazemskega senčenja. Rezultati kažejo, da je plazemsko senčenje močno odvisno od intenzitete laserskega žarka in dolžine laserskega bliska. Ob pojavu plazemskega senčenja se izkoristek laserskega obdelovalnega procesa močno zmanjša. Numerične rešitve kažejo, da višja intenziteta laserskega žarka povzroči bolj intenzivno plazemsko senčenje in zato nižji izkoristek. Zato je za zvišanje izkoristka laserskega procesa koristno poznati vpliv procesnih parametrov na lastnosti plazemskega oblaka [2]. Dobro ujemanje numeričnih in eksperimentalnih rezultatov obeta možnosti določitve procesnih parametrov, ki zmanjšujejo neželeni vpliv plazemskega senčenja.

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Model and Characterisation of Laser-Induced Plasma Plume Formation

ROBERT ROZMAN, IGOR GRABEC and EDVARD GOVEKAR

Laboratory of Synergetics
University of Ljubljana, Faculty of mechanical engineering,
Aškerčeva 6, SI-1000 Ljubljana, Slovenia
robert.rozman@fs.uni-lj.si • www.fs.uni-lj.si/lasin

High intensity laser beam material processing is accompanied by evaporation of irradiated target. At certain conditions, the absorption coefficient in plasma increases, causing an increase of laser beam energy absorption in the plasma plume. Due to this, portion of laser beam energy does not reach the target surface and heating of the target can be significantly decreased. In laser material processing this phenomenon is known as plasma shielding. The proposed model of laser-induced plasma plume formation [1] describes the thermal phenomena caused by high intensity laser beam irradiated at the target. The heating of the target is described by a heat equation together with thermally activated surface evaporation. The flow of evaporated material from the target surface is governed by the system of compressible Navier-Stokes equations, where the evaporated material and ambient gas are treated as ideal ionized gases. Description of absorption coefficient of plasma for laser beam includes three different processes: inverse bremsstrahlung process, photoionization process and process of absorption on small condensed clusters. All thermal phenomena considered in the model are formulated using complicated non-linear equations that are solved numerically in 2-D space. The numerically calculated results of the model are compared with experimental measurements and show good agreement of calculated results with experimental results. Based on the model results the plasma shielding phenomenon is characterized. Results show that plasma shielding varies with pulse duration and depends on laser beam intensity. Due to the onset of plasma shielding, the efficiency of laser material processing is significantly decreased. The numerically calculated results show that higher laser beam intensity usually cause more intensive plasma shielding and therefore lower processing efficiency. Therefore, to increase the efficiency of laser material processing, it is useful to know the influ-

ence of process parameters on the properties of the laser-induced plasma [2]. Good agreement of modelling and experimental results offer is promising to use the model to determine optimal parameters that minimize the effect of plasma shielding.

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A Markov processes associated with the car parking and land distribution in the city

PETR SEBA

Institute of Physics, Academy of Sciences of the Czech Republic, Prague - Czech Republic
University of Hradec Králové, Hradec Králové - Czech Republic
seba@fzu.cz

We describe the probability distribution of distances between parked cars as a solution of certain Markov process. We show that the steady solution is obtained with the help of a distributional fixed point equation. Under certain conditions this process can be explicitly solved. The resulting probability density is compared with the actual parking data measured in the city.

Using a similar approach we analyze also the size distribution of land plots in the Czech Land Registry. We show the coincidence of the plot size density with the probability distribution of the largest prime factor of a random integer.

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Van der Waals forces between nanostructures

MARIJAN ŠUNJIĆ

Department of Physics, University of Zagreb
Bijenička 32, HR-10000 Zagreb

In the first part I shall described the advances in experimental techniques (controlled sample preparation and characterization, various spectroscopies and scanning probe microscopies) and theoretical methods (both as data analysis support and as explanation of new phenomena) that have led first to the successful development of surface physics as an important branch of solid state physics, with relevance not only to other fields of physics but especially to numerous technological applications. Further progress led from surfaces to the study of heterostructures and other quantum confined structures of reduced size and symmetry - quantum wells, wires, tubes and dots, as well as the their combinations, and exploded into a field that is now called nanophysics or more generally nanoscience. In the second part I want to mention briefly some of the characteristic new phenomena in nanophysics and their theoretical treatment, as well as the difficulties in formulating the many body formalism in finite and inhomoheneous systems. As a "canonical" example I shall one such approach to the dynamical response and excitations in (single and coupled) metallic (jellium!) thin films. In the final part I shall discuss two applications of this formalism: to develop a microscopic theory of the van der Waals interaction between thin metallic slabs and to calculate and discuss the inelastic spectra in XPS from core levels near surfaces.

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Dinamično tuneliranje v gobastem biljardu

GREGOR VIDMAR

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

Predstavil bom koeficiente tuneliranja iz regularnega v kaotično območje pri gobastem biljardu. Primerjal bom rezultate mikrovalovnega eksperimenta, teoretične napovedi vključujoč namišljen integrabilni sistem in numeričnih izračunov s splošno in specialno metodo, prilagojeno gobastemu biljardu. Našli smo zelo dobro ujemanje v ekperimentalno in numerično dostopnem območju nizkih energij.

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Dynamical tunneling in mushroom billiard

GREGOR VIDMAR

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

Dynamical tunneling rates from the regular region to the chaotic sea in mushroom billiard will be presented, comparing results from a microwave experiment, an analytic prediction using a fictitious integrable system, and numerical calculation using general and special method, adapted for mushroom billiard. Very good agreement in the experimentally and numerically accessible regime of low energies has been found.

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Dynamical systems on time scales

YEPENG XING

Department of Mathematics, Shanghai Normal University
Shanghai, P.R. China

I shall focus on a new area of mathematics, dynamic systems on time scales, which was first introduced by two German mathematicians: Bernd Aulbach and Stefan Hilger in 1988

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. The purpose of this new dynamical equations can be described as: Unification – Extension – Discretization. We know the theory of differential and difference equations form two extreme representations of real world problems. For example, a simple population model when represented as a differential equation shows a good (regular) behavior of solutions whereas the corresponding discrete analogue shows the chaotic behavior. The actual behavior of the population is somewhere in between. So it makes sense to study a system unifying differential and difference calculus in one framework. Now there are two monographs [2,3] on this topic. As is well known, integro-differential equations find many applications in various mathematical problems, see Cordunean's book [4]. Some of our recent works are of the integro-differential equations on time scales [5,6,7]. We obtain some new results of the existence of solutions for boundary value problems of integro-differential equations on time scales.

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Prepletenost in simulacija kvantnih sistemov

MARKO ŽNIDARIČ

Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenija
marko.znidaric@fmf.uni-lj.si • chaos.fiz.uni-lj.si

Časovna zahtevnost simulacije kvantnih sistemov narašča eksponentno z velikostjo sistema. To pomeni, da nismo sposobni izračunati lastnosti niti najpreprostejših eno dimenzionalnih kvantnih sistemov. Ker so lahko fizikalne lastnosti rešljivih modelov bistveno drugačne, kot pa lastnosti generičnih sistemov, bi bilo zelo zaželeno izračunati vsaj nekatere lastnosti, eksponentni zahtevnosti navkljub. Postavlja se vprašanje, katere so količine, ki jih lahko vseeno izračunamo? Znano je, da je izračun lastnosti osnovnih stanj eno dimenzionalnih sistemov učinkovit. Predstavil bom rezultate, ki kažejo na to, da je možno izračunati tudi nekatere druge stvari. Izkaže se, da je računska zahtevnost tesno poveza s kvantno prepletenostjo.

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Entanglement and simulability of quantum systems

MARKO ŽNIDARIČ

Faculty of Mathematics and Physics
University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
marko.znidaric@fmf.uni-lj.si • chaos.fiz.uni-lj.si

Computational comlexity of simulating quantum systems grows exponentially with their size. This means that we are not able to calculate properties of even very simple one dimensional systems. As physical properties of exactly solvable models can be very different from those of generic ones, i.e., non-solvable or in solid state language of strongly correlated systems, there is a great need to nevertheless calculate at least some quantities. The question arises which quantities are, despite an exponential complexity, nevertheless ameanable to an efficient calculation? It is known that ground state properties od 1d systems are one such case. Are there any other? I will try to present few other cases where the calculation is possible as well as mentioning some negative results where the best present day metods fail. It turns out that the computational complexity is intimately connected to the entanglement.

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Nematske pletenice s koloidnimi delci disklinacijami

SLOBODAN ŽUMER in MIHA RAVNIK

Oddelek za fiziko, Fakulteta za matematiko in fiziko
Univerza v Ljubljani, Jadranska 19, 1000 Ljubljana, Slovenija
Institut Jožef Stefan, Jadranska 19, 1000 Ljubljana, Slovenija
slobodan.zumer@fmf.uni-lj.si

V predavanju bom opisal naš napredek pri modeliranju koloidnih struktur v ograjenem nematiku. Tekoči kristal posreduje večdelčno interakcijo in s tem omogoča nastanek kompleksnih struktur, ki so zelo občutljive na vrsto ograditve in na zunanja polja. Poleg regularnih mrežnih struktur, kjer za povezave skrbe lokalizirani nematski defekti, nas bodo posebej zanimale strukture, kjer defekti niso lokalizirani. V takem primeru disklinacije tvorijo nematske pletenice, ki koloidne delce vežejo kot nekake strune. Nadalje si bomo ogledali, kako v mešanici velikih in majhnih koloidnih delcev pride do nastanka zanimivih hierarhičnih struktur. Predstavljene strukture nakazujejo možnosti za samoorganizacijo fotonskih sistemov in formiranje metamaterialov. Ogledali si bomo, kako se naše napovedi skladajo z novimi eksperimenti skupine profesorja Muševiča.

Nematic braids with colloidal particles lines

SLOBODAN ŽUMER in MIHA RAVNIK

Department of Physics, Faculty of Mathematics and Physics
University of Ljubljana, Jadranska 19, 1000 Ljubljana, Slovenia
Jozef Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia
slobodan.zumer@fmf.uni-lj.si

Our recent advancements in modeling of complex colloidal structures in nematic liquid crystals are described and compared to new experimental findings. Liquid crystal mediated many-body interactions lead to complex colloidal structures that are particularly sensitive to the confinement and field effects. Colloidal superstructures that are coupled by an entangled network of delocalized nematic disclination lines are contrasted to regular lattices of colloidal particles coupled by localized defects. Formation of colloidal dimmers, trimers, chains, and braids is illustrated. Although many structures are metastabile the string-like coupling makes them very resistant to perturbations. Further we illustrate the behavior of a mixture of small and large colloidal particles that leads to an interesting hierarchical organization where small particle decorate disclination lines that entangle large particles. The resulting colloidal structures open new ways to the assembling of colloidal photonic crystals and hierarchical structures that can lead to metamaterials.


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