CAMTP
Center for Applied Mathematics and Theoretical Physics
Univerza v Mariboru

# 14. Simpozij fizikov Univerze v Mariboru

## Zbornik povzetkov

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Maribor, 10., 11. in 12. december 2015

| | |
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Generalni pokrovitelj simpozija:

EASA - European Academy of Sciences and Arts (Salzburg)

## PREDGOVOR

Naši Simpoziji fizikov Univerze v Mariboru, ali na kratko kar Božični simpoziji fizikov, imajo že tradicijo, saj imamo letos že štirinajstega po vrsti. Namen je strokovno druženje slovenskih fizikov, ob prisotnosti ter aktivni udeležbi nekaterih uglednih kolegov iz tujine kot častnih vabljenih gostov. Letos imamo sedem uglednih vabljenih predavateljev iz tujine, iz odličnih raziskovalnih skupin, tako da s tem ostajajo naša srečanja nacionalna z mednarodno udeležbo. Srečanje je le ena od številnih dejavnosti CAMTP - Centra za uporabno matematiko in teoretično fiziko Univerze v Mariboru, ki sicer organizira kar sedem serij mednarodnih znanstvenih srečanj. Glejte **www.camtp.uni-mb.si**.

Radi bi poudarili, 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. Kolegi iz tujine, dosedanji udeleženci, potrjujejo to stališče in cenijo naš znanstveni program. Simpozij daje priložnost mladim raziskovalcem, da predstavijo svoje delo ter se o svojih rezultatih pogovorijo z izkušenimi znanstveniki. S to dejavnostjo prispevamo tudi k popularizaciji fizike v naši družbi, na trajen način. 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 radi poudarili, da je naše druženje pomemben prispevek pri nadaljnjih uspešnih aktivnostih Fakultete za naravoslovje in matematiko Univerze v Mariboru, ter Fakultete za matematiko in fiziko Univerze v Ljubljani, in seveda inštitutov z oddelki za fiziko, kot sta Inštitut Jošef Stefan v Ljubljani ter CAMTP v Mariboru.

V čast nam je, da je generalni pokrovitelj in soorganizator našega srečanja Evropska akademija znanosti in umetnosti (European Academy of Sciences and Arts, Salzburg).

Srečanje je posvečeno 85. rojstnemu dnevu Profesorja Siegfrieda Grossmanna z Univerze v Marburgu, Nemčija, ki je častni doktor (Doctor honoris causa, 2011) Univerze v Mariboru in ima velike zasluge za razvoj CAMTP Univerze v Mariboru ter za njegove mednarodne povezave. Profesor Grossmann, ki se je rodil 28. februarja 1930 v Königsbergu (Vzhodna Prusija, danes Kaliningrad, Rusija), od leta 1964 pa deluje kot profesor na Univerzi v Marburgu, kjer je bil leta 1998 upokojen, je eden najvidnejših teoretičnih fizikov 20. in 21. stoletja, saj je eden utemeljiteljev nelinearne dinamike kot nove znanstvene discipline, hkrati pa je eden svetovno vodilnih teoretikov na področjih hidrodinamike ter teorije turbulence, stohastičnih procesov, faznih prehodov, fizike laserjev, jedrske fizike, transportne teorije, Bose-Einsteinove kondenzacije ter splošne statistične fizike, kakor tudi matematične fizike in funkcionalne analize. Dodajmo še, da sta Univerzi v Marburgu in v Mariboru partnerski univerzi, Marburg in Maribor pa pobrateni mesti. Profesor Grossmann je tako veliko prispeval h kulturni in znanstveni izmenjavi med mestoma in njunima univerzama.

Prof. Dr. Marko Robnik, član EASA, Direktor CAMTP
in Doc. Dr. Anita Prapotnik Brdnik, FGPA UM

## FOREWORD

Our Symposia of Physicists at the University of Maribor, or shortly Christmas Symposia, already have a tradition, as this year it is already the 14th one. The purpose is the scientific socializing of Slovenian physicists along with the participation of some distinguished colleagues from abroad as our honorary guests. This year we have six invited speakers from abroad, from some best research groups, so that our meetings remain national with international participation. The meeting is only one of the many activities of CAMTP - Center for Applied Mathematics and Theoretical Physics, which organizes seven series of international scientific meetings. See **www.camtp.uni-mb.si**.

We would like to stress that our meeting is devoted to the entire physics, theoretical and experimental, and also applied mathematics and to all other topics, for which physics is important, or they are important for physics.

All lectures are on the level of colloquia, thus understandable for a general physicist, and therefore particularly well suited for students, the undergraduate and graduate students. Such general meetings in the field of physics practically no longer exist in the world, although to our opinion they are important for the widening of the intellectual horizon of all physicists. Our colleagues from abroad, the participants so far, confirm our view and appreciate our scientific programme. The meeting is also an opportunity for the young researchers to present their work and discuss it with the experienced scientists. With this activity we also contribute to the promotion and the popularization of physics in our society. We are convinced that it is quite urgent to care about the more intense popularization of natural sciences in our society, and physics plays a key role in this context. All undergraduate students can attend all the lectures of the conference free of charge. In this way we contribute to the popularization of physics and to the additional education in this field.

At the end we would like to stress that our gatherings are an important contribution to the activities of the Faculty of Natural Sciences and Mathematics of the University of Maribor and the Faculty of Mathematics and Physics of the University of Ljubljana, and of course also for the institutes with the department of physics, like Institute Jožef Stefan and CAMTP in Maribor.

It is our privilege that the general patron and co-organizer of our meeting is the European Academy of Sciences and Arts (Salzburg).

The meeting is dedicated to the 85th birthday of Professor Siegfried Grossmann from the University of Marburg, Germany, who is Honorary Doctor (Doctor honoris causa, 2011) of the University of Maribor; he has the credits for the development of CAMTP and its international relationships. Professor Grossmann, born on 28 February 1930 in Königsberg, East Prussia (now Kaliningrad, Russia), working at the University of Marburg since 1964, where he was retired in 1998, is one of the most outstanding theoretical physicists of the 20th and 21st Centuries, as he is one of the founders of the nonlinear dynamics as the new scientific discipline, and also is one of the world-wide leading theoreticians in the fields of fluid dynamics and theory of turbulence, stochastic processes, phase transitions, laser physics, nuclear physics, transport theory, Bose-Einstein condensation and the general statistical physics, as well as mathematical physics and functional analysis. We should mention that Universities of Marburg and Maribor are partner universities, and Marburg and Maribor are twin cities. Therefore, Professor Grossmann has contributed a lot to the enrichment of the cultural and scientific exchange between the two cities and their universities.

Prof. Dr. Marko Robnik, Member of EASA, Director of CAMTP
and Prof. Dr. Anita Prapotnik Brdnik, FGPA UM

**LAUDATIO**
**in Honour of**
# Professor Siegfried Grossmann
**of the University of Marburg, Germany**
**by**
**Professor Dr. Marko Robnik, Director of CAMTP**

Ladies and Gentlemen, Your Excellency, respected Rector Professor Igor Tičar, respected Professor Ludvik Toplak, Member of the Senate of the European Academy of Sciences and Arts, and President of the Alma Mater Europaea, Evropski Center Maribor, respected distinguished guests!

Professor Siegfried Grossmann from the University of Marburg, Germany, is one of the greatest theoretical physicists of the 20th and 21st centuries, in the worldwide context. He is Honorary Doctor (Doctor honoris causa, 2011) of the University of Maribor and has the credits for the development of CAMTP and its international relationships. Professor Grossmann, born on 28 February 1930 in Königsberg, East Prussia (now Kaliningrad, Russia), is working at the University of Marburg since 1964, where he was retired in 1998

He is one of the founders of the nonlinear dynamics as the new scientific discipline, and also is one of the world-wide leading theoreticians in the fields of fluid dynamics and theory of turbulence, stochastic processes, phase transitions, laser physics, nuclear physics, transport theory, Bose-Einstein condensation and the general statistical physics, as well as mathematical physics and functional analysis. We should mention that Universities of Marburg and Maribor are partner universities, and Marburg and Maribor are twin cities. Therefore, Professor Grossmann has contributed a lot to the enrichment of the cultural and scientific exchange between the two cities and their universities.

His scientific life opus in the numerous research fields of theoretical physics is immense and deserves the highest international recognition. Indeed, Professor Grossmann has received many high ranking awards and honours. Among them I should mention only a few most important ones:

• In 1991 he was elected full member of the European Academy of Sciences and Arts

• In 1994 he was elected full member of the Berlin-Branderburgische Akademie der Wissenschaften, where since then he also holds important functions

• In 1994 he was elected full member of the Deutsche Akademie der Naturforscher Leopoldina

• In 1995 he was awarded the Max-Planck-Medal of the German Physical Society, the highest award for physics

• In 1996 he was awarded the Grosses Verdienstkreuz des Verdienstordens der Bundesrepublik Deutschland

• In 2006 he received the Honorary Doctorate of the University of Duisburg-Essen

• In 2011 he received the Honorary Doctorate of our University of Maribor

• In 1995-2002 he was a member of the Senate of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF)

• In 1998-2000 he was the President of the Senate Committee for the strategy fond of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF)

• In 1990-1992 he was President of the committee for fundamental research of the Federal Ministry for Research and Technology of the German Government

• Furthermore, he was the president or a member of numerous other committees and bodies, such as: Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren, Federal ministries of the German Government, German Research Society, Committee for nominations of the Leibniz Award, Minerva Center for Nonlinear Dynamics of Complex Physical Systems, "Network Nonlinear Dynamics" of the European Science Foundation, the scientific council of the German Electron Synchrotron (DESY) in Hamburg, Ombudsman of the German Research Society.

• Last but not least, in 2005 he was awarded the Seal of the City of Maribor by the mayor of our city of Maribor, Mr. Boris Sovič.

Professor Grossmann is not only a leading scientist and important adviser and authority in the domain of natural and other sciences, but also an excellent educator. He has educated a great number of excellent theoretical physicists, as doctoral students, as postdoctoral coworkers, and as his assistants. Most of them became well known outstanding researchers and professors all over the world. As examples I should mention Professor Peter Richter of the University of Bremen, who was one of the first, unfortunately he passed away last May, then Professor Bruno Eckhardt, who is now full professor at the University of Marburg, and was a recipient of the Leibniz Award, which is the highest national award for science in Germany, and Professor Detlef Lohse of the University of Twente in Enschede, The Netherlands, who also is a recipient of the Spinoza Award, the highest award for science in The Netherlands.

Regarding his work connected with the University of Maribor, I would like to mention the following.

Professor Grossmann is one of the five Honorary Directors of our world-top international Summer Schools and Conferences "Let's Face Chaos through Nonlinear Dynamics", taking place every three years at the University of Maribor, under the organization of CAMTP, namely along with other leaders in the field, Professors: Giulio Casati, Como, Italy, Predrag Cvitanović, Atlanta, USA, Theo Geisel, Göttingen, Germany, and Hermann Haken, Stuttgart, Germany. He is also a major invited lecturer since 1994. He has also kindly contributed a paper to all of our conference proceedings so far. In 2005 the gathering was dedicated to his 75th birthday, and in 2010 the 9th Christmas Symposium was dedicated to his 80th birthday. His support of - and collaboration with - CAMTP, the Center for Applied Mathematics and Theoretical Physics of the University of Maribor, was very important and highly appreciated since 1994.

Professor Grossmann has initiated a most successful scientific cooperation between my group at CAMTP with the group of Professor Hans-Jürgen Stöckmann at the

University of Marburg, in the field of quantum chaos, which started in 1996, when I was visiting there, based on a kind invitation by Professor Grossmann. Since then the cooperation between CAMTP and University of Marburg has developed very strongly. Three PhD students of mine were involved in this cooperation, and many coworkers on the German side. We have numerous joint original scientific publications with the group of Professor Stöckmann, who is also with us at this meeting, and on this occasion I thank him sincerely as well for the great scientific cooperation over the past two decades. Also, we have three joint papers with Professor Grossmann.

But there are also other activities, organized jointly with the University of Marburg, namely with Professor Stöckmann, and always kindly and strongly supported by Professor Grossmann. The so-called SOCRATES workshops on classical and quantum chaos, which took place twice in Marburg (namely 2004 and 2008), and twice in Maribor (in 2004 and 2009). In addition, there are the Christmas Symposia of Physicists of the University of Maribor, the present one is already the 14th in the series, where Professor Grossmann has attended several times, and, moreover, we have almost every year several other participants, invited speakers, distinguished guests from the University of Marburg, especially Professor Hans-Jürgen Stöckmann. The colleagues from Marburg very often participate also at the Japan-Slovenia Seminars on Nonlinear Science as invited external honorary guests and speakers, which have a long tradition, since 1999, and we had so far 14 of them, both in Slovenia and in Japan. Also, Professor Grossmann has kindly accepted our invitation to be a member of the international board of directors of the European Advanced Studies Conferences, which we have initiated with Professor Andreas Ruffing from the Technical University of Munich, and Professor Tassos Bountis from the University of Patras, Greece, who is also with us at this meeting. I sincerely thank him as well, for the excellent cooperation over more than twenty years.

Finally, I should mention that Professor Siegfried Grossmann at his high age of 85 is still scientifically active, publishing important research papers every year, and also giving lectures at conferences and seminars.

Therefore, I may conclude, that scientific work and academic support by Professor Grossmann for the CAMTP - Center for Applied Mathematics and Theoretical Physics and for the Faculty of Natural Sciences and Mathematics of the University of Maribor, is invaluable, and that Professor Grossmann is an eminent Ambassador of Science of the University of Maribor.

At the end, I wish to quote the words of Professor Peter Richter and Professor Detlef Lohse, both his former PhD students, and also eminent scientists by themselves, saying the following:

"Thinking of Siegfried, the planets and stars remind us of Immanuel Kant with whom he shares not only the birthplace (Königsberg, East Prussia, now Kaliningrad, Russia), but also many standards and virtues: as teacher, thinker, and as a man of wisdom and influence."

Unfortunately, this time he is not able to attend our meeting due to some health problems.

Therefore, we, all the participants of our gathering, send to him our message:

Happy birthday, and thank you, Siegfried, for all that you have done for all of us: Alles Gute für Dich und vielen herzlichen Dank!

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# Urnik 14. Simpozija fizikov Univerze v Mariboru

| **Četrtek, 10. december 2015** | |
|---|---|
| Chair | Robnik |
| 09:00-09:30 | Opening |
| 09:30-10:30 | Žumer |
| 10:30-11:15 | Shudo |
| 11:15-11:45 | Coffee & Tea |
| 11:45-12:30 | Prosen |
| 12:30-13:00 | Trontelj |
| 13:00-13:30 | Ramšak |
| 13:30-15:00 | Lunch |
| Chair | Prapotnik Brdnik |
| 15:00-15:45 | Perc |
| 15:45-16:30 | Fajfer |
| 16:30-17:00 | Coffee & Tea |
| 17:00-17:45 | Stöckmann |
| 17:45-18:00 | Kukuljan |
| 19:00-20:00 | Concert I |
| 20:00-22:00 | Banquet I |

| **Petek, 11. december 2015** | |
|---|---|
| Chair | Stöckmann |
| 09:00-09:45 | Bonča |
| 09:45-10:30 | Prelovšek |
| 10:30-11:15 | Dvorak |
| 11:15-11:45 | Coffee & Tea |
| 11:45-12:30 | Dolinšek |
| 12:30-13:00 | Stožer |
| 13:00-13:30 | Gosak |
| 13:30-13:45 | Vidmar |
| 13:45-15:00 | Lunch |
| Chair | Prosen |
| 15:00-16:00 | Guhr |
| 16:00-16:45 | Ravnik |
| 16:45-17:15 | Coffee & Tea |
| 17:15-18:00 | Robnik |
| 18:00-18:45 | Žnidarič |
| 19:00-20:00 | Concert II |
| 20:00-22:00 | Banquet II |

| **Sobota, 12. december 2015** | |
|---|---|
| Chair | Guhr |
| 09:00-09:45 | Zorko |
| 09:45-10:30 | Bountis |
| 10:30-11:00 | Medenjak |
| 11:15-11:45 | Zadnik |
| 11:15-11:45 | Coffee & Tea |
| 11:45-12:30 | Grozdanov |
| 12:30-13:15 | Tribelsky |
| 13:15-13:30 | Rosina |
| 13:30-13:45 | Vogrin |
| 13:45-15:00 | Lunch |
| Chair | Tribelsky |
| 15:00-15:45 | Šarler |
| 15:45-16:30 | Prapotnik Brdnik |
| 16:30-17:00 | Coffee & Tea |
| 17:00-17:45 | Romanovski |
| 17:45-18:15 | Ferčec |
| 18:15-18:30 | Dukarič |
| 18:30-18:45 | Bajc |
| 19:00-22:00 | Dinner |

# Metoda projeciranega faznega podprostora v perspektivi posplošenega Gibbsovega ansambla

IZTOK BAJC

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Nedavne študije [1] so pokazale, da nekatere vidike hidrodinamskega toka lahko učinkovito študiramo prek dinamične analize le nekaj primerno izbranih načinov. Koristno bi bilo, če bi jih lahko vključili v nekaj podobnega termostatu iz kanoničnega ansambla [2]. Za prostostne stopnje, ki so povezane s turbulentnostjo, si nasplošno pričakujemo, da zapolnjujejo svoj predel faznega prostora (skoraj) v celoti. Če slednjo uspemo ograditi v dobro definirane (pod)domene fizičnega prostora, bi lahko delovala kot posplošen termostatski sistem. Fazni portret važnejšega, manjšega sistema (za preprostost in vizualizacijo raje z 2d/3d faznim podprostorom) bi v njem nekako "plaval", šibko interagirajoč s turbulentnim področjem. Matematična analiza takega sistema bi lahko uporabljala orodja iz Riemannove geometrije, kot evolucijo metrik na mnogoterostih, tako teoretično kot numerično [3]. Centralna mnogoterost je ponavadi najvažnejša in jo za številne polinomske sisteme lahko dobimo prek algebraičnih metod [4]. Stohastične efekte bi lahko vključili npr. s [5].

**Reference**

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# Projected phase subspace approach towards a generalized Gibbs ensemble for hydrodynamics

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Recent studies [1] showed that certain aspects of a hydrodynamic flow can be effectively studied through dynamical analysis of a few well chosen modes. It would be useful if they might be embedded into something similar as the thermostat from the canonical ensemble [2]. Degrees of freedom related to turbulent flow are expected to fill up (almost) all their phase space region. If confined into well defined physical space (sub)domains, they may possibly act as such a generalized thermostatting system. The phase portrait of the more important, smaller system (for simplicity and visualization aims with 2d/3d phase subspace) would "float" in it, weakly interacting with the turbulent region. The mathematical analysis of such a system could try to use tools from Riemannian geometry, as metric evolution on manifolds, both theoretically and numerically [3]. The center manifold is usually the most crucial one, which for several polynomial systems can be obtained by algebraic methods [4]. Stochastic effects can be included by [5].

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# Relaksacija in termalizacija po fotoekscitaciji

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V prvem delu bom predstavil fundamentalno študijo relaksacijske dinamike ene vrzeli v dvo dimenzionalnem $t$-$J$ modelu po vzbuditvi z močno perturbacijo. Ob upoštevanju kvantno mehanske narave problema sledimo časovnemu razvoju sistema od začetnega močno vzbujenega stanja do stacionarnega stanja. Relaksacija poteka preko neelastičnega sipanja foto-vzbujenega nosilca naboja na spinskih ekscitacijah v časovni skali cca 10 fs [1,2]. V tem ultra-hitrem času se presežek 1eV foto vzbujene energije porazdeli med bližnje spinske vezi.

V drugem delu bom predstavil primarni relaksacijski proces foto vzbujenega nosilca naboja sklopljenega z Einsteinovimi fononi [3]. V kolikor je začetni pulz dovolj močan se sistem približa stacionarnemu stanju. Tedaj enodelčna gostotna matrika ter optična prevodnost zavzameta obliko, značilno za termično ravnovesje. Naši rezultati kažejo, da so stacionarna stanja termična ter, da lahko njihovo temperaturo določimo iz poteka optične prevodnosti kot funkcije frekvence. Od tod sledi ključni rezultat: sekundarne relaksacijske procese, ki jih opazijo v časovno ločljivih optičnih meritvah, lahko zadovoljivo opišemo z metodami, ki veljajo v termičnem ravnovesju, kot so na primer večtemperaturni modeli.

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# Relaxation and thermalisation after photoexcitation

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In the first part, I will present a fundamental study of the relaxation dynamics of a single hole in the two dimensional t-J model initially excited by a strong quench. Taking fully into account quantum effects we follow the time-evolution of the system from a highly excited state until it reaches a steady state. Relaxation occurs on the time- scale of 10 f s due to inelastic scattering of a photo-excited carrier on spin excitations [1,2]. Within this ultrafast relaxation time an excess of 1 eV of initial photo absorbed energy by the doped charge carrier is distributed among neighboring spin bonds.

In the second part I will discuss the primary relaxation process of a photo excited charge carrier coupled to quantum Einstein phonons [3]. If the pump pulse is sufficiently strong, the system relaxes after the primary energy redistribution towards a steady state. Then, the one-particle density matrix relevant for charge degrees of freedom along with the optical conductivity take up the form of their thermal counterparts. Our results indicate that steady states are (quasi)thermal and the temperature can be read out from the optical conductivity. Therefore, secondary relaxation processes observed in time resolved ultrafast spectroscopy can be efficiently described by applying (quasi)thermal approaches, e.g., the many-temperature models.

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# From Mechanical to Biological Oscillator Networks: The Role of Long Range Interactions

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The study of one-dimensional particle networks of Classical Mechanics, through Hamiltonian models, has taught us a lot about oscillations under nearest neighbor (short range) interactions. Recently, however, through a careful analysis of the role of long range interactions (LRI), several widely accepted notions concerning chaos and the approach to thermal equilibrium have been challenged based on studies of the statistics of certain very interesting, long lasting metastable states. On the other hand, when LRI (in the form of non-local or all-to-all coupling) was introduced in systems of biological oscillators, Kuramoto's 1st theory of synchronization was developed and soon thereafter researchers studied amplitude and phase oscillations in networks of FitzHugh Nagumo and Hindmarsh Rose (HR) neuron models. In these models certain fascinating phenomena called chimera states were discovered where synchronous and asynchronous oscillations coexist. Currently, their synchronization properties are being widely investigated in HR mathematical models as well as realistic neural networks, similar to what one finds in simple living organisms like the *C.elegans* worm.

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# Visokoentropijske kovinske spojine

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V zadnjih letih so bile razvite konceptualno nove kovinske zlitine, sestavljene iz več večinskih kemijskih elementov v enakih ali približno enakih molarnih razmerjih. Te zlitine so bile poimenovane visokoentropijske kovinske spojine (ang. High-Entropy Alloys - HEA) [1,2]. Velika entropija mešanja, ki je posledica slučajnega mešanja kemijskih elementov na kristalni mreži, stabilizira kemijsko neurejeno trdno raztopino s preprosto kristalno strukturo, kot so npr. telesno centrirana kubična (bcc) mreža, ploskovno centrirana kubična (fcc) mreža in heksagonalni gosti sklad (hcp). V primerjavi z urejenimi kristalnimi intermetalnimi spojinami, ki imajo velikokrat ogromno osnovno celico, imajo HEA zlitine majhno osnovno celico. Za strukturo HEA zlitin je značilna topološko urejena kristalna mreža z izjemno velikim kemijskim neredom zaradi naključne razporeditve atomov različnih kemijskih elementov na mrežnih mestih, zato lahko HEA zlitino smatramo kot "kovinsko steklo na urejeni kristalni mreži". Veliko entropijo mešanja dosežemo v zlitinah sestavljenih iz petih ali več kemijskih elementov v primerljivih koncentracijah, to je med 5 in 35 atomskih odstotkov za vsak element, hkrati pa nobeden izmed elementov ne sme preseči koncentracije 50%. Primeri HEA zlitin so sistemi Al-Si-Co-Cr-Cu-Fe-Mn-Ni-Ti, W-Nb-Mo-Ta-V in Ta-Nb-Hf-Zr-Ti. HEA zlitine je možno sestaviti iz velike množice različnih kemijskih elementov, katerih koncentracije lahko precej poljubno spreminjamo v širokem intervalu. Zato je število različnih možnih HEA zlitin praktično neomejeno. Kljub temu so doslej raziskali le okrog deset HEA zlitin, zato je področje še skoraj povsem neraziskano. Leta 2014 je raziskovalni skupini z Instituta Jožef Stefan uspel mednarodni preboj na tem področju - odkritje prve superprevodne HEA zlitine Ta-Nb-Hf-Zr-Ti [3].

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# High-Entropy Alloys

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Traditionally, metallic alloy systems have been based mainly on one principal chemical element as the matrix, even though a substantial amount of other elements is incorporated for property/processing enhancement. Within the past several years, a new approach to alloy design with multiple principal elements in equimolar or near-equimolar ratios, termed high-entropy alloys (HEAs), has been proposed [1,2]. According to this concept, high entropy of mixing can stabilize disordered solid solution phases with simple structures like a body-centered cubic (bcc), a face-centered cubic (fcc) and a hexagonal close-packed (hcp) lattice and prevent formation of intermetallic phases during solidification. In order to achieve high entropy of mixing, the alloys must be composed typically of five or more (up to thirteen) major elements in similar concentrations, ranging from 5 to 35 at. % for each element, but do not contain any element whose concentration exceeds 50 at. %. Examples are HEAs with bcc or fcc structure within the systems Al-Si-Co-Cr-Cu-Fe-Mn-Ni-Ti, W-Nb-Mo-Ta-V, and Ta-Nb-Hf-Zr-Ti. It has been demonstrated that HEAs exhibit enhanced mechanical properties like high hardness and solid-solution strengthening. Recently we have synthesized the first superconducting HEA with composition $Ta_{34}Nb_{33}Hf_8Zr_{14}Ti_{11}$ (in at. %), which possesses a disordered lattice with an average bcc structure of lattice parameter $a = 0.336$ nm. The measurements of the electrical resistivity, the magnetic susceptibility and the specific heat revealed that the $Ta_{34}Nb_{33}Hf_8Zr_{14}Ti_{11}$ HEA is a type II superconductor with a moderately high transition temperature $T_c \approx 7.3$ K, an upper critical field of 8.2 T, a lower critical field of 35 mT and an energy gap in the electronic density of states at the Fermi level of 2.2 meV [3].

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# Integrabilnost kubičnega Lotka-Volterrovega sistema

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Integrabilnost je redek pojav, vendar zelo pomemben za razumevanje dinamike sistema navadnih diferencialnih enačb. Predstavljena bo študija integabilnosti Lotka-Volterrovega sistema oblike

$$\dot{x} = x(1 - a_{10}x - a_{01}y - a_{20}x^2 - a_{11}xy - a_{02}y^2),$$
$$\dot{y} = -y(1 - b_{10}x - b_{01}y - b_{20}x^2 - b_{11}xy - b_{02}y^2).$$

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# Integrability of cubic Lotka-Volterra system

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The integrability is a rare phenomena, but important for understanding the dynamics of systems of ordinary differential equations. We present some results on integrability of Lotka-Volterra system of the form

$$\dot{x} = x(1 - a_{10}x - a_{01}y - a_{20}x^2 - a_{11}xy - a_{02}y^2),$$
$$\dot{y} = -y(1 - b_{10}x - b_{01}y - b_{20}x^2 - b_{11}xy - b_{02}y^2).$$

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# On the formation of the Moon

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Our study consists of three separated parts concerning the formation of the Moon due to a catastrophic collision of a Mars-sized body - often referred to as Theia - with the early Earth. The first one deals with planet-formation in the early Solar System, the second one with the dynamical evolution of the planets Venus, Earth, Mars, Jupiter and Saturn and an additional planet (Theia) between Earth and Mars and the third one with the proposed giant collision itself and its outcome concerning masses and water contents of the resulting bodies (or fragments), computed via Smoothed Particle Hydrodynamics (SPH) simulations.

More precisely we will deal with the following:

1. The formation of the early planetary system can be explained e.g. by the so-called Grand Tack model, where the giant planets formed prior to the terrestrial planets. In one out of 50 of our N-body simulations, where we model collisional-growth of planetesimals to - eventually - planets, starting with Jupiter and Saturn on their present orbits, in fact an additional planet - Theia - between Earth and Mars was formed, with the other planets having more or less their actual orbital parameters.

2. With these results in mind we have undertaken massive N-body integrations with Theia starting at different positions between the planets. Our goal was to find stable orbits for these Mars-sized planets for up to almost 100 million years, before this very regular dynamical evolution ends, and a short chaotic behavior eventually leads to a collision with Earth. Although the probability of such a specific orbit is small, we found a few (out of thousands) which fulfilled this criterion. Finally, these computations provided the necessary collision parameters for the subsequent SPH computations.

3. Our preliminary model constitutes an early Earth of one Earth-mass and an impactor of 1/10 this mass. Both bodies consist primarily of Basalt, with the early Earth featuring a water shell in the order of one mass-percent. However, the soon planned extension by an additional iron-core will be a major step towards a more realistic model of the bodies' composition. While parameters like possible involved masses and impact velocities have already been investigated in step 2, we focus on the fate of possible water reservoirs during this proposed giant collision in this part. This allows us to draw implications on the origin of Earth's water and to assess its connection to this popular Moon-forming hypothesis. Besides tracing the system's dynamics, its thermal evolution is also of particular interest to us. It allows to assess the basic physical conditions and eventually to estimate the amount of water-losses due to outgassing and escape.

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# Higgsov bozon in kršitev leptonskega števila

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Nedavno so na pospeševalniku LHC izmerili razvejitveno razmerje za razpad Higgsovega delca v muon in tau lepton. Obravnavo smo začeli z uporabo najbolj splošnega opisa nove fizike in izpeljali robustno mejo na sklopitev Higgsovega bozona, muona in tau leptona. Potem smo določili dodatne meje, ki prihajajo iz nizkoenergijskih opazljivk. Zlasti, naj bi vpliv omenjene sklopitve bil opazen v razpadu $\tau \to \mu\gamma$, katerga bi lahko opazili v načrtovanih poskusih na Belle II. Po drugi strani bomo pokazali, da se opaženo odstopanje od napovedi Standardnega modela za razpadno širino za $H \to \mu\tau$ lahko razloži le v modelih z razširjenim skalarnim sektorjem. Te splošne ugotovitve smo ilustrirali v različnih modelih Nove fizike.

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# Higgs boson and lepton number violation

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Recently, Large Hadron Collider has observed an excess in the observed branching ratio for Higgs decay to muon and tau leptons. First, we consider most general new physics contribution and derive a robust lower bound on the Higgs boson coupling strength to a tau and a muon. Then, we reevaluate complementary indirect constraints coming from low energy observables as well as from theoretical considerations. In particular, the tentative signal should lead to $\tau \to \mu\gamma$ rates, which could be observed at Belle II. In turn we show that, the effect can only be accommodated within models with an extended scalar sector. These general conclusions are demonstrated using a number of explicit new physics models.

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# Kvalitativni študij kemijsko reakcijskega sistema

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Izvedemo kvalitativni študij reverzibilnega kemijsko reakcijskega modela, ki je predstavljen s tri-dimenzionalnim sistemom navadnih diferencialnih enačb z devetimi parametri. Predstavili bomo pristop za določitev geometrijske strukture faznega prostora in iskanje Hopfovih bifurkacij v polinomskih sistemih odvisnih od večih parametrov (takšni sistemi so tipično v modelih biokemijskih omrežij), ki kombinira nekatere metode kvalitativne analize avtonomnih sistemov diferencialnih enačb in učinkovite metode in programsko opremo komutativne algebre. Predlagane metode uporabimo za iskanje invariantnih ploskev in pogojev za parametre, pod katerimi v sistemu, ki ga obravnavamo, nastopi Hopfova bifurkacija.

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# The qualitative study of a chemical reaction system

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

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# Kritično prostorsko-časovno obnašanje medceličnih $Ca^{2+}$ valov v pankreasnih celicah beta

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Samoorganizirana kritičnost (SOK) je fizikalni koncept, ki se nanaša na pojav spontane samopodobne dinamike v različnih kompleksnih sistemih, katerih območje delovanja se nahaja med redom in stohastičnostjo [1]. Ti sistemi imajo skupno značilnost, da aktivacija enega elementa aktivira tudi druge, kar vodi do propagacije plazov aktivnosti po sistemu. Koncept SOK predvideva, da je prostorska in/ali časovna razsežnost teh plazov skalno invariantna, kar se ozdraža na potenčni porazdelitvi velikosti posameznih plazov. V nevroloških sistemih se pojav SOK povezuje s prisotnostjo kritične dinamike, za katero so značilni optimalen prenos informacij, maksimalen dinamičen doseg ter optimalno procesiranje [2]. V tej študiji se osredinimo na preučevanje obstoja mehanizmov SOK v prostorko-časovni dinamiki povezanih celic beta, ki predstavljajo prevladujoč tip celic v Langerhansovih otočkih. Te endokrine celice med drugim izločajo hormon inzulin in so ključnega pomena pri fiziološkem in patofiziološkem uravnavanju koncentracije hranil v telesu. Izmerjeno dinamiko $Ca^{2+}$ valov kvantificiramo na podlagi porazdelitve velikosti prostorsko-časovnih skupkov [3]. Naši rezultati kažejo na to, da so razsežnosti vzorcev $Ca^{2+}$ aktivnosti porazdeljene potenčno, kar pa ne pomeni le še enega potencialnega primera SOK v realnih sistemih, temveč vodi tudi do novih spoznanj o funkcionalni organiziranosti $Ca^{2+}$ signalizacije v otočkih. Za pridobitev bolj poglobjenega vpogleda v mehanizme, ki vodijo do kritičnega obnašanja, smo izdelali tudi fenomenološki večcelični matematični model sklopljenih celic beta. S sistematičnim preučevanjem vloge različnih parametrov smo ugotovili, da sta heterogenost celic in narava medcelične skopitve ključna dejavnika, ki vodita do potenčnega obnašanja. Pridobjena spoznanja izboljšajo naše razumevanje uravnavanja dinamike na ravni tkiva in to tudi v širšem kontekstu drugih večceličnih sistemov.

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# Critical spatio-temporal behavior of intercellular $Ca^{2+}$ waves in pancreatic beta cells

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Self-organized criticality (SOC) is a concept proposed in physics and refers to the spontaneous emergence of self-similar dynamics in various complex systems poised between order and randomness [1]. In such systems, as one unit exceeds a threshold, this in turn provokes the activation of other units, thereby leading to avalanches of activity that propagate through the system. The concept asserts that the spatial and/or temporal extent of such avalanches is characterized by scale invariance, which is usually identified as a power-law distribution. In neuronal systems, the notion of SOC is associated with the emergence of critical dynamics, which was shown to lead to optimized information transmission, maximized dynamic range and optimal computational capabilities [2]. In the present study we examine if the fingerprints of SOC concepts can also be found in the spatio-temporal dynamics of interconnected beta cells from islets of Langerhans, endocrine cells that reside in the pancreatic tissue, synthesize and release insulin, and play a pivotal role in normal and pathological whole-body nutrient homeostasis. We quantify the coherence of the spatiotemporal organization of $Ca^{2+}$ waves by calculating the distribution of the space-time cluster sizes [3]. Our results reveal a power law scaling in the cluster-size distribution, thereby giving not only another possible example of SOC in a real-life system, but also offering novel insights into the functional organization of $Ca^{2+}$ signaling in islets. Moreover, we build up a phenomenological multicellular model of coupled beta cells, on the basis of which we can systematically explore the circumstances that lead to critical behavior. Our findings indicate that both cell-to-cell variability and the extent of intercellular coupling are the crucial determinants for the power-law scaling. Our results also provide new insights into the emergent multicellular dynamics in general which are applicable to other multicellular physiological systems.

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# Bounds on thermo-electric conductivities in simple holographic models

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The gauge/gravity (or AdS/CFT) duality has proven to be a very useful tool for studying certain classes of strongly-coupled field theories. Its success has particularly been due to the connection it established between gravitational perturbations and hydrodynamics. Using these techniques, I will present new insight into the behaviour of strongly disordered condensed matter systems and their thermoelectric transport. After presenting the duality and its hydrodynamic limit, I will discuss lower bounds on thermal and electric conductivities in a large family of non-perturbative, strongly disordered holographic models. These are candidate models for exotic, strange metals without long-lived quasiparticles. Finally, I will discuss further characteristics that a holographic dual of a disorder-driven metal-insulator transition and a many-body localised state should exhibit.

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# Chaotic Scattering: New Exact Results and Comparison to Microwave Experiments

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A major part of our knowledge about quantum systems stems from scattering experiments. Often, the scatterer is a highly complex or chaotic system, allowing one to set up models involving random matrices. This was done in the Mexico and in the Heidelberg approaches. In the former, the scattering matrix itself, and in the latter the Hamiltonian describing the interaction zone (the scatterer), respectively, are modeled by random matrices. A long-standing problem was to compute the distribution of the scattering matrix elements which is of considerable practical and theoretical interest. While the distribution of the diagonal elements could be calculated some years ago within the Heidelberg approach, the distribution of the off-diagonal elements continued to resist analytical treatment. Recently we managed to fully solve this problem for systems with preserved and with violated time-reversal invariance. We validated our results with scattering data obtained from experiments with flat microwave billiards, which are known to simulate quantum mechanics in two dimensions.

# Renormalizabilna metoda za 2D kvantno neravnovesno fiziko

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Neravnovesna dinamika močno sklopljenih kvantnih mnogodelčnih sistemov je mlado, zelo aktivno in še relativno neraziskano področje fizike. Teoretiki se pri svojem delu pogosto opirajo na teorijo integrabilnosti po eni in renormalizabilne numerične metode po drugi strani. Oboje je za zdaj povezano z 1D sistemi, zato je večina teoretičnih rezultatov omejenih na eno krajevno dimenzijo. Predstavil bom enega prvih korakov v dvodimenzinalno močno sklopljeno kvantno neravnovesno fiziko. V sklopu magistrske naloge sva z mentorjem, Tomažem Prosenom, obravnavala neravnovesni 2D kvantni Isingov model. Za namen izračuna gostote njegovega kvazienergijskega spektra sva razvila renormalizabilno numerično metodo, s pomočjo katere je možno obravnavati 2D kvantne dinamične sisteme.

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# A renormalizable method for 2D non-equilibrium quantum physics

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Non-equilibrium dynamics of strongly coupled many-body quantum systems is a young, very active and relatively unexplored area of physics. The theory often relies on theory of integrability on one side and renormalizable numerical methods on the other. Both are so far related to 1D systems. Therefore, the majority of the theoretical results in the field are currently limited to one-spatial dimension. I will present one of the first steps into the 2D strongly coupled non-equilibrium quantum physics. In my master project under the supervision of Tomaž Prosen, we studied the kicked 2D quantum Ising model. To compute the level density of its quasi-energy spectrum, we developed a renormalizable numerical method that is applicable to studying 2D quantum dynamical systems.

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# Efektivno lokalne ohranjene količine v izotropni Heisenbergovi verigi

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Eno izmed glavnih vprašanj statistične fizike je, kako opisati pričakovane vrednosti lokalnih opazljivk po dolgem času. Pri tem igrajo osrednjo vlogo ohranjene količine [1]. Te so osrednjega pomena tudi v teoriji linearnega odziva [2]. Integrabilnost kvantne Heisenbergove verige nam za neskončen sistem zagotavlja obstoj neskončnega števila lokalnih integralov gibanja. Izkaže se, da je statistični opis napačen, če se omejimo le na množico lokalnih ohranjenih količin [3,4]. Za pravilen opis je potrebno upoštevati množico vseh efektivno lokalnih ohranjenih količin [5]. Na primeru izotropne Heisenbergove verige bom predstavil splošno konstrukcijo efektivno lokalnih ohranjenih količin, ki so linearno neodvisne od lokalnih integralov gibanja [6].

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# Quasilocal conserved quantities in isotropic Heisenberg spin chain

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One of the main goals of statistical physics is to find an ensemble for the correct description of expectation values of local observables. Conserved quantities play the central role in this description [1] as well as in linear response theory [2]. Due to the integrability, quantum Heisenberg spin chain possesses an infinite set of local conserved operators in the thermodynamic limit. If we consider only the local conserved quantities, the statistical description is inaccurate [3,4]. To provide the correct description one needs to take into account the full set of quasilocal conserved quantities [5]. I will present, on an example of the Heisenberg spin chain, a general construction of the quasilocal conserved quantities, which are linearly independent from the local integrals of motion [6].

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# Stoletje fizike: Identifikacija znanstvenih memov in njihovih vzorcev dedovanja

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Dvajseto stoletje je zaznamovano kot stoletje fizike. Od x-žarkov do polprevodniške industrije, dejstvo je, da bi človeška družba danes bila bistveno drugačna brez inovacij, ki so plod fizikalnih laboratorijev širom po svetu. Informacija v preko pol milijona publikacij American Physical Society, ki so nastale v preteklih 119 letih, in ki so nam danes na voljo v digitalni obliki, se lahko uporabijo za natančno kvantifikacijo trendov napredka, ter za identifikacijo najvplivnejših znanstvenih memov. Z identifikacijo vseh unikatnih besed in besednih zvez ter njihovih mesečnih vzorcev uporabe ugotovimo, da se pogostost uporabe primerno opiše s porazdelitvijo, ki ima težak rep, in da je izvor slednjega pogojen z "Matejevim efektom". Podatki tudi razkrijejo, da obdobja vojn močno upočasnijo napredek, in da je slednji podvržen močnim trendom globalizacije. Na podlagi teh raziskav smo sposobni izpeljati preprosto zvezo, ki nam razkrije vzorce dedovanja znanstvenih memov v citatnih mrežah. Slednji so podobni temu kako se uspešni geni dedujejo skozi generacije v človeških družbah.

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# A century of physics: The identification of scientific memes and their inheritance patterns

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The 20th century is often referred to as the century of physics. From x-rays to the semiconductor industry, the human society today would be very different were it not for the progress made in physics laboratories around the world. The information provided in the digitized content of over half a million publications that were published by the American Physical Society during the past 119 years can be used to quantify trends of progress, and to identify the most influential scientific memes. By identifying all unique words and phrases and determining their monthly usage patterns, one finds that the magnitudes of upward and downward trends yield heavy-tailed distributions, and that their emergence can be attributed to the Matthew effect. The data also confirm that periods of war decelerate scientific progress, and that the latter is very much subject to globalization. This research can be further extended towards a simple regularity that allows us to identify the inheritance patterns of scientific memes in citation networks, which are akin to how successful genes propagate through generations in human societies.

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# Radiativni razpadi mezonov $D$ negativne in pozitivne parnosti

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Predstavila bom radiativne razpade $D$ mezonov pozitivne in negativne parnosti v sliki kiralne perturbacijske teorije težkih mezonov. Kiralna perturbacijska teorija težkih mezonov je primerna za opisovanje razpadnih kanalov mezonov z enim težkim in enim lahkim kvarkom pri katerih razpadni produkti nimajo prevelikih gibalnih količin. S pomočjo obstoječih eksperimentalnih podatkov bomo določili sklopitvene konstante med fotonom in težkimi mezoni in poskušali napovedati še neizmerjene razpadne širine. Zlasti nas bodo zanimale napovedi za radiativne razpade $D_{s1}(2460)^+$ in $D^*_{s0}(2317)^+$ mezonov. Njuni izmerjeni masi sta namreč precej nižji od tistih, ki jih napoveduje teorija. Zato se je porodil sum, da mezona $D_{s1}(2460)^+$ in $D^*_{s0}(2317)^+$ v resnici nista navadni $\bar{q}q$ stanji, ampak je njuna struktura kompleksnejša (stanje štirih kvarkov, $DK$ molekula, itd...). Nekaj uvida v strukturo mezonov $D_{s1}(2460)^+$ in $D^*_{s0}(2317)^+$ lahko dobimo s proučevanjem njunih razpadnih kanalov. Sodeč po [1], strukturo $D_{s1}(2460)^+$ in $D^*_{s0}(2317)^+$ mezona bi najlažje opazili ravno s študijo radiativnih razpadov.

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# Radiative decays of pozitive and negative parity $D$ mesons

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I will present the study of radiative $D$ meson decays of both negative and positive parity in the picture of Heavy meson chiral perturbation theory. Heavy meson chiral perturbation theory can be used to describe decay channels of mesons containing one light and one heavy quark in which the particles after decay have small recoil momenta. We will try to determine the radiative coupling constants of heavy mesons inside the HM$\chi$PT as well as predict decay widths of radiative $D$ meson decays that are still unmeasured. We are especially interested in the decay widths of the $D_{s1}(2460)^+$ and $D^*_{s0}(2317)^+$ states. Namely, the experimental measurements have shown that the $D_{s1}(2460)^+$ and the $D^*_{s0}(2317)^+$ masses are much smaller than the values predicted form the theoretical models. It was an indication that the $D_{s1}(2460)^+$ and $D^*_{s0}(2317)^+$ may not be a regular $\bar{q}q$ states, but are of more complex nature (four-quark state, $DK$ molecule, etc...). Some insight into the structure of the $D_{s1}(2460)^+$ and $D^*_{s0}(2317)^+$ states can be obtained by studying their decay rates. According to [1], the radiative decay channels of $D^*_{s0}(2317)^+$ and $D_{s1}(2460)^+$ should be most sensitive to the structure of these two mesons.

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# Mottovi izolatorji izven ravnovesja

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V predavanju bom predstavil nekatere teoretične koncepte pri obravnavi snovi, kjer je izvor izolatorskih lastnosti močan Coulombski odboj med elektroni. V teh snoveh je možno obravnavati nizko-vzbujena stanja znotraj Hubbardovega enopasovnega modela, pri čemer predstavljajo relevantne vzbuditve nezasedena mesta (holoni) in dvojno zasedena mesta (dubloni). Vezavo med holoni in dubloni je možno tudi vzeti kot mehanizem za prehod kovina - izolator v takih sistemih. Po drugi strani pa novi eskperimenti t.im. pump - probe spektroskopije omogočajo direkten vpogled v lastnosti Mottovih izolatorjev. Posebej je zanimiva in presenetljiva zelo hitra relaksacija k ravnovesju v teh materialih, in s tem povezan hitri transientni odziv elektronov. Predstavljena bo teorija, ki razloži obstoj vmesnega ekscitonskega stanja in temu sledečo zelo hitro rekombinacijo nabojev, povezano z emisijo večih bozonov. Slednji so v planarnih kupratih magnoni, v enodimenzionalnih organskih izolatorjih pa fononske prostostne stopnje.

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# Mott insulators out of equilibrium

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In the talk I will discuss some theoretical aspects of materials where the origin of insulating behaviour is the Coulomb repulsion between electrons. Low-lying excited states in the prototype Hubbard model can be then discussed in terms of doubly occupied sites (doublons) and empty sites (holons). Moreover, the binding of holons and doublons can serve as the mechanism for the metal-insulator transition. At present the pump-probe spectroscopy opens a novel view on the properties of Mott insulators, and in particular it reveals surprisingly fast relaxation to the equilibrium and interesting transient charge response. I will present a theory based on the existence of the holon-doublon exciton and its recombination, which explains the decay in terms of multi-boson emission. We show that relevant bosons in planar cuprates are spin excitations, while in one-dimensional organic insulators the decay goes via phononic degrees of freedom.

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# Matrično-produktne rešitve robno-gnanih kvantnih verig

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V predavanju bom predstavil kratek pregled [1] nedavnega napredka pri konstrukciji točnih rešitev stacionarnih stanj neravnovesnih kvantnih verig, ki jih poganja kontakt s parom dissipativnih rezervoarjev na robovih. Ključen koncept je matrično-produktni nastavek, ki vodi do kompaktne in uporabne formulacije točnega reševanja. Metodo bom orisal na nekaterih paradigmatičnih primerih, kot je npr. anizotropen Heisenbergov model spinov 1/2, Hubbardov model, in integrabilen (permutacijski) model spinov 1.

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# Matrix product solutions of boundary driven quantum chains

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In my talk I will review [1] recent progress on the construction of exact steady state solutions of nonequilibrium quantum chains which are driven through contacts with a pair of with dissipative reservoirs at the chain ends. The key concept is the matrix product ansatz which leads to a very compact and useful formulation of integrability of such nonequilibrium models. The method will be sketched on several paradigmatic examples, such as the anisotropic Heisenberg spin 1/2 chain, the Hubbard model, and the permutation model of spins 1.

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# Poljubne transformacije kvantnih bitov na obročih z Rashbovo sklopitvijo

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Najprej bomo predstavili koncept geometijskih faz v klasični in kvantni mehaniki, in sicer od Hannayevega kota [1] do Berryjeve faze [2] in nato do ne-adiabatne ne-Abelske Anandanove faze [3]. Motivacija je manipulacija spina elektrona samo z zunanjimi električnimi polji.

Nato bomo predstavili točne rešitve za elektron v kvantni žici s časovno odvisno sklopitvijo spin-tir in časovno odvisnim električnim poljem [4, 5]. Na osnovi teh rešitev lahko analitično izrazimo vse znane geometrijske faze, in sicer Anandanovo fazo in v adiabatni limiti fazo Wilczka in Zeeja [6], kar omogoča holonomično transformacijo kvantnih bitov. Z zlomom simetrije na obrat časa rezultati reproducirajo fazo Anandana in Aharonova [7] ter v adiabatni limiti običajno Berryjevo fazo.

Pri gibanju v eni dimeziji smo omejeni na rotacijo spina okoli fiksne osi. To omejitev lahko odpravimo na kvantnem obroču v prisotnosti časovno odvisnih Rashbove sklopitve in zunanjega potenciala. S premikanjem po segmentih obroča je možno uztrezno definiran Kramersov pseudo-spin transformirati v poljubno točko Blochove sfere, s čimer so končno izvedljive splošne operacije s kvantnimi biti [8].

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# Arbitrary qubit transformations on Rashba rings

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A brief introduction to the concept of geometric phases in classical and quantum mechanics will be given, from the Hannay angle [1] to the Berry phase [2] and to the non-adiabatic non-Abelian Anandan phase [3]. The motivation is the manipulation of electron spin, in particular, by locally applying external electric fields.

Next, we will present exact solutions for an electron in a quantum wire with time dependent spin-orbit interaction and driven by external time-dependent potential [4, 5]. By the virtue of the exact solution one can construct analytically the corresponding Anandan phase or in the adiabatic limit the Wilczek-Zee phase [6], which enables holonomic qubit transformations. By breaking the time reversal symmetry the results lead to the Aharonov-Anandan phase [7] and in the adiabatic limit reproduce the usual Berry phase.

Finally, an exact solution will be presented for the time-dependent wavefunction of a Kramers-doublet which propagates around a quantum ring with tuneable Rashba spin-orbit interaction. By propagating in segments the Kramers-doublet qubits may be defined for which transformations on the full Bloch sphere may be performed for an integral number of revolutions around the ring [8].

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# Pasivna in aktivna nematska mikrofluidika

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Mikrofluidika na osnovi kompleksnih aktivnih in pasivnih nematskih tekočin omogoča različne mehanizme za nadzor tokovnih profilov, krmiljenje toka, tokovno mešanje in transport delcev, kar vse temelji na sklopitvi med tokom in notranjim molekularnim orientacijskim redom. V tem prispevku predstavimo modelsko študijo, v sodelovanju s partnerskimi eksperimenti, ki razišče sklopitev med geometrijo in orientacijskim urejanjem v aktivni in pasivni nematski mikrofluidiki. V preprostih geometrijah opazimo, da je geometrija dokaj neposredno senčena tako v direktorskem kot tokovnem profilu, razen če se ne ustvarijo topološki defekti. V bolj zapletenih kanalih in geometrijah opazimo tvorbo različnih topoloških defektov, kot pogojenih z različnimi tokovnimi profili. Pokažemo, da se simetrija in topologija defektov lahko nastavlja z geometrijo kanalov. V aktivni mikrofluidki pokažemo, da aktivni defekti delujejo kot mikro-črpalke za tok. Splošneje z načrtovanjem orienatiacijskih profilov aktivnega ali pasivnega nematika lahko kontroliramo profile in možno topologijo materialnega toka.

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# Passive and active nematic microfluidics

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Microfluidics based on complex active and passive nematic fluids gives access to different mechanisms for controlling flow profiles, flow steering, flow mixing and particle transport, all relying on the coupling between the flow and the internal molecular order. Here, we present our modelling study, in collaboration with partner experiments, that explores the coupling between geometry and orientational ordering in active and passive nematic microfluidics. We observe that in simple channels the geometry gets rather directly screened in both the flow and director profile,unless if generating topological defects. In more complex channels and geometries, we observe formation of different topological defects, as generated by the variable flow profiles. The symmetry and topology of defects is shown to be controllable by the geometry of the channel. For active micfolfuidic, we show that active defects act as local micro-pumps for the material flow. More generally, by designing the orientational profile of active or passive nematic we can control the profile and possibly topology of the material flow.

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# Uporaba WKB metode v 1D linearnih in nelinearnih časovno odvisnih oscilatorjih

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Metoda WKB je pomembno analitično orodje za reševanje številnih problemov v matematični fiziki 1D sistemov, kot je n.pr. stacionarna (časovno neodvisna) Schrödingerjeva enačba v eni dimenziji, ali pa *klasična dinamika* enodimenzionalnih časovno odvisnih (neavtonomnih) hamiltonskih oscilatorjev. Podal bom pregled standardne WKB metode vključno z eksaktnimi eksplicitnimi rešitvami *do vseh redov*, ki sta jih objavila Robnik in Romanovski (2000), in uporabila v seriji člankov. Med drugim sta pokazala, da uporaba metode v primerih Schrödingerjeve enačbe eksaktno rešljivih potencialov privede do neskončne vrste prispevkov vseh redov, da ta vrsta konvergira in njena vsota reproducira znane eksaktne lastne energije. Posebej si bomo ogledali primer časovno odvisnega enodimenzionalnega linearnega hamiltonskega oscilatorja, nato pa bom predstavil pristop k posplošitvi WKB metode za primer enodimenzionalnih časovno odvisnih nelinearnih hamilotonskih oscilatorjev s kvadratično kinetično energijo ter homogenim potenčnim potenticialom, kar vključuje n.pr. kvartični oscilator, in seveda linearni oscilator. Pokazal bom, da je nelinearna metoda, čeprav samo v vodilnem približku, zelo koristna in natančna. Dotaknili se bomo tudi možnih posplošitev.

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# Application of the WKB method in 1D linear and nonlinear time-dependent oscillators

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The WKB method is an important analytic tool for solving numerous problems in mathematical physics of 1D systems, for example the stationary (time-independent) Schrödinger equation in one dimension, or the *classical dynamics* of one-dimensional time-dependent (nonautonomous) Hamilton oscillators. I shall review the standard WKB method including the exact explicit solutions *to all orders*, published by Robnik and Romanovski (2000), and applied in a series of papers. Among other results they have shown that the application of the method in cases of the Schrödinger equation with exactly solvable potentials leads to an infinite series to all orders, that the series converges and the sum reproduces the known exact eigenenergies. We shall look in particular at the case of the time-dependent one-dimensional linear Hamiltonian oscillator, and then I shall present the approach towards generalizing the WKB method for the case of one-dimensional time-dependent nonlinear Hamiltonian oscillators having quadratic kinetic energy and homogeneous power law potential, which includes e.g. the quartic oscillator, and of course also the linear oscillator. I will show that the nonlinear method, although only in the leading approximation, is very useful and accurate. We also shall touch upon possible generalizations.

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# Izohronost in linearizabilnost polinomskih Hamiltonskih sistemov

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Obravnavamo problema izohronosti in linearizabilnosti za dvo-dimenzionalne polinomske sisteme NDE. Predstavil bom nekaj študij povezanih z odprtim problemom Jarque in Villadelprata: ali obstaja dvo-dimenzionalni polinomski Hamiltonski sistem sodega reda, ki ima izohroni center. Predstavil bom tudi nekatere rezultate o linearizabilnosti kompleksnih Hamiltonskih sistemov.

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# Isochronicity and linearizability of polynomial Hamiltonian systems

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We discuss isochronicity and linearizability of planar polynomial systems. In particularly, we present some study on the open problem stated by Jarque and Villadelprat: do there exist planar polynomial Hamiltonian systems of even degree having an isochronous center? We also give some results on linearizability of complex cubic Hamiltonian systems.

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# Primerjava med čarobnimi dimezoni in vodikovo molekulo

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Predstavil bom zanimivo primerjavo med "molekulo" iz dveh mezonov in vodikovo molekulo. Posebno zanimivi so dimezoni iz dveh težkih (čarobnih) mezonov.Na bližino elektrostatska sila protona v vodikovi molekuli odbija, kromodinamska interakcija pa dva težka (čarobna) kvarka privlači, ker lahko ustrezno preklopita barvni naboj.

Odkrivanje resonanc – sistemov z dvema kvarkoma in dvema antikvarkoma ("tetrakvarkov") je zelo aktivno področje hadronske fizike, tako eksperimentalno kot teoretično. Tetrakvarke, pri katerih prevladuje konfiguracija z dvema gručama v obliki mezonov, imenujemo dimezone. Tetrakvarki predstavljajo zelo poučen zgled problema štirih teles, zanimiv tudi z matematičnega vidika. Nudijo pa tudi priložnost za študij efektivne interakcije med kvarki, ali je res univerzalna za lahke in težke kvarke.

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# Comparison between charmed dimesons and hydrogen molecule

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I shall present an interesting comparison between the "molecule" of two mesons and the hydogen molecule. Especially interesting are dimesons made of two heavy (charmed) mesons. At short distance, the two protons in the hydrogen molecule are repelled by the electrostatic interaction, while the two heavy (charm) quarks are attracted by the chromodynamic interaction because they can recouple their colour charge.

The detection and the interpretation of resonances in systems with two quarks and two antiquarks ("tetraquarks") is a very lively topic in hadronic physics. Tetraquarks where the configuration with two meson-like clusters dominates are usually called dimesons. Tetraquarks offer a very instructive example of the four-body problem, also interesting mathematically. They offer also the opportunity to study the effective interaction between quarks, whether it is really universal for light and heavy quarks.

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# Nesingularna metoda temeljnih rešitev v mehaniki trdnin in tekočin

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Reševanje parcialnih diferencialnih enačb z linearno kombinacijo temeljnih rešitev predstavlja klasični pristop matematične fizike. Pristop je bil v zadnjih dveh desetletjih postavljen v okvir računalniške fizike ter uporabljen za reševanje nelineranih, anizotropnih in časovno odvisnih problemov. V primeru singularne temeljne rešitve zahteva metoda postavitev izvorov zunaj računskega področja za uskladitev rešitve z robnimi pogoji. Opisano predstavlja glavno pomanjkljivost te brezmrežne metode. Pokažemo več originalno razvitih desingularizacijskih tehnik, ki dovoljujejo postavitev izvornih točk na rob tudi v primeru singularne temeljne rešitve. Diskutiramo njihovo formulacijo ter konvergenco. Pokažemo praktično uporabo metode v večdimenzijskih primerih iz mehanike tekočin kot sta npr. potencialni in Stokesov tok s premičnimi robovi in mehanike trdnin kot npr. deformacija sistemov sestavljenih iz anizotropnih elastičnih zrn. Prikazana je tudi praktična uporaba te nove metode v mikrofluidiki.

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# Non-Singular Method of Fundamental Solutions in Solid and Fluid Mechanics

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Solution of partial differential equations by a linear combination of fundamental solutions represents a classical approach of mathematical physics. This approach has been in the last two decades put in the context of computational physics and applied to non-linear, anisotropic and time-dependent problems. In case of singular fundamental solution, the method requires arrangement of the sources outside of the computational domain in order to comply with the boundary conditions. This represents a main drawback of such meshless method. We show several originally developed regularization strategies of the method that allow to put the sources on the boundary also in the case of singular fundamental solution. We discuss their formulation issues and convergence properties. We show practical application of the method in multidimensional examples from fluid mechanics such as potential and Stokes flow with moving boundaries, and solid mechanics such as deformation of systems composed of anisotropic elastic grains. The practical application of this novel method in microfluidics is shown as well.

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# The existence of infinitely many stability islands and sticky dynamics in a piecewise linear map

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In generic Hamiltonian systems which are neither completely integrable nor fully chaotic, phase space is a mixture of regular and chaotic components. We here discuss classical dynamics in mixed phase space by studying a piecewise linear map [1]. In particular, we will focus on a situation in which hierarchical islands appear in phase space and provide a rigorous proof for the existence of infinitely many stability islands by introducing a proper symbolic dynamics [2]. We also discuss the effect of hierarchical islands on the stickiness of dynamics [3-4].

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# Spectral properties of mixed phase space systems

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A report on microwave studies of billiards with mixed phase will be given, which had been performed during the past decade in my quantum chaos group in Marburg, Germany, in cooperation with the groups of Marko Robnik, Maribor, Slovenia and Arnd Bäcker, Roland Ketzmerick, Dresden, Germany.
The classical dynamics of a quantum-mechanical system shows up in its spectral properties, in particular the spacing distribution of neighbouring eigenvalues. For mixed phase space systems Berry and Robnik (BR) [1] derived a level spacing distribution interpolating between the Poisson distribution found in regular systems and the Wigner distribution observed in completely chaotic systems. The approach assumes independent contributions to the spectrum from the different phase space regions, which obviously can be correct only in the semiclassical limit. In the low energy regime the BR distribution fails in particular to describe the spacing distribution for small spacings correctly. In this talk I shall present a number of of microwave studies which had been performed in Marburg on mixed phase space billiards, e.g. on an analytic modification of the BR distribution [2] (with Maribor), dynamical tunneling in mushroom billiards [3] (with Maribor, Dresden) and resonance assisted tunneling [4] (with Dresden).

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# Preučevanje učinkov potencialnega novega zdravila za sladkorno bolezen: od klasičnih fizioloških do novih večplastnih mrežnih pristopov

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Sladkorna bolezen je pogubna kronična presnovna bolezen, za katero je v letu 2013 obolevalo 400 milijonov bolnikov, do leta 2035 pa naj bi jih po predvidevanjih e skoraj 600 milijonov (Guariguata, Whiting, et al.). Globalno breme bolezni dodatno povečujejo zapleti bolezni, ki se vsaj delno pojavljajo zaradi naše nezmožnosti, da bi uspešno preprečevali oziroma zdravili sladkorno bolezen (Tahrani, Bailey, et al.). Farmakološki agensi iz obstoječega nabora možnosti zdravljenja niso zmožni zaustaviti napredovanja bolezni in sulfonilsečnine, ki celice beta vzpodbujajo k izločanju inzulina na od glukoze neodvisen način, so povezane z visokim tveganjem za hipoglikemične epizode, ki so lahko smrtne, predvsem pa pomembno zmanjšujejo adherenco bolnikov do zdravljenja (Cryer 2013). V prizadevanjih po odkritju novih možnosti zdravljenja smo nedavno pokazali, da antagonist receptorjev tipa NMDA dekstrometorfan predstavlja obetavno novo zdravilo, saj podaljša trajanje oscilacij znotrajcelične koncentracije kalcijevih ionov, ki predstavljajo sprožilni signal za izločanje inzulina (Marquard, Otter, et al. 2015). Ker je bilo pokazano, da celice beta, ki izločajo inzulin, tvorijo kompleksno mrežo (Stožer, Gosak, et al. 2013), ki jo lahko modificirajo zunanji fiziološki (Markovič, Stožer, et al. 2015) in patofiziološki dražljaji (Hodson, Mitchell, et al. 2013), bodo nadaljnje študije učinkov farmakoloških agensov, kakršen je dekstrometorfan, s pomočjo paradigme kompleksnih mrež nasploh, predvsem pa na podlagi pristopa z uporabo večslojnih

mrež lahko pripomogle k našemu razumevanju delovanja potencialnega novega zdravila na tkivni ravni.

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# Studying the effects of a possible new drug for diabetes mellitus: from classical physiological to novel multilayer network approaches

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Diabetes mellitus is a devastating chronic metabolic disease that affected approximately 400 million people worldwide in 2013 and this number is expected to rise to almost 600 million by the year 2035 (Guariguata, Whiting, et al.). The global burden of the disease is further increased by diabetic complications that are at least partly due to our inability to successfully prevent or treat diabetes mellitus pharmacologically (Tahrani, Bailey, et al.). Pharmacological agents from the existing armamentarium of treatment modalities are unable to halt the progression of the disease and sulphonylureas which stimulate beta cells in a glucose-independent manner are also associated with a high risk of hypoglycemic episodes that can be fatal but also importantly lower patient adherence (Cryer, 2013). In a quest to find novel treatment modalities, we have recently demonstrated that the NMDA-receptor antagonist dextromethorphan is a promising new possibility which prolongs the duration of cytosolic calcium oscillations which are the triggering signal for insulin release (Marquard, Otter, et al. 2015). Since the insulin-secreting beta cells have been shown to constitute a complex network (Stožer, Gosak, et al. 2013) that can be influenced by external physiological (Markovič, Stožer, et al. 2015) and pathophysiological stimuli (Hodson, Mitchell, et al. 2013), studying the effects of a pharmacological agent, such as dextromethorphan, by applying the complex network paradigm in general and specifically the multilayer network approach can help

us understand the effects of a potential drug at the multicellular level.

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# Steady and chaotic patterns in weakly supercritical distributed systems

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A review of pattern formation in highly nonequilibrium extended dissipative systems close to the onset of a short-wavelength instability is presented. It is shown that in 1D cases, regardless the specific set of the governing equations, the description of the problem may be reduced to a solution of a single parameter-free generic equation. Such an equation is the properly scaled Ginzburg-Landau one. However, if the system in question possesses an additional (to trivial translational and rotational) continuous group of symmetry, the pattern formation problem is changed dramatically. In particular, in this case a direct transition from a quiescent state to spatiotemporal chaos with very unusual properties may become possible. The transition is a nonequilibrium analog of second order phase transitions in statistical physics and inherits many features of the latter (critical slowing down, divergence of the correlation length at the transition points, etc.). Comparison of the developed theory with experiments is discussed too.

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# Magnetometer z optičnim črpanjem in njegova uporaba pri nizkofrekvenčni radiofrekvenčni spektroskopiji ter elektrofizioloških meritvah

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Kvantitativna magnetometrija se je začela z Gaussom in njegovim magnetometrom 1832 in nadaljevala s Hallom, Foersterjem in njunima magnetometroma do več vrst magnetometrov, ki so jih razvili iz nekaterih spektroskopij pa vse do kvantnih magnetometrov (SQUID magnetometer). Ti magnetometri omogočajo natančne meritve zemeljskega magnetnega polja, magnetizma različnih snovi pa vse do meritev magnetnih polj, ki izvirajo iz elektrofizioloških aktivnosti. Z drugimi besedami - z njimi lahko merimo magnetna polja velikosti od $10^{-5}$ T pa do $10^{-15}$ T in manj. Magnetometer s parami alkalnih kovin (K ali Rb ali Cs), o katerem bomo govorili, lahko doseže občutljivost nekaj $10^{-16}$ T (nekaj desetink fT) in njegova teoretska občutljivost presega občutljivost danes najbolj občutljivega SQUID (superconductive quantum interference device) magnetometra. Čeprav so magnetometri s parami alkalnih kovin poznani že od 1957 (Dehmelt[1,2], Bell in Bloom[3], Kastler[4]), je bil potreben stabilen, uglasljiv diodni laser, da je bilo mogoče v zadnjem desetletju doseči omenjeno visoko občutljivost. Predstavili bomo princip delovanja takega magnetometra in se zadržali podrobneje pri magnetometru s parami kalija (K). Nato bomo prikazali dve praktični uporabi takega magnetometra pri RF spektroskopiji nizkih frekvenc ($^{14}$N NQR) in pri kvazi DC meritvah vzbujene aktivnosti možganske skorje, ki registrira audio signale.

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# Optically Pumped Magnetometer: Its Application in Low Frequency RF Spectroscopy and in Electrophysiologic Measurements

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Usually, C. F. Gauss with his magnetometer (1832) is considered as the first-one in the group of researchers, followed by Hall, Foerster and others with their magnetometers, who contributed to the quantitative magnetometry. The development continues with magnetometers coming as applications of some spectroscopies and we will stop it at macroscopic quantum devices SQUID magnetometers. All these magnetometers enable us to measure with high precision magnetic fields from the Earth's magnetic field to magnetization of different materials and also magnetic fields caused by the electrophisiologic activities of some organs. That means, we can measure magnetic fields from $10^{-5}$ T to $10^{-15}$ T and less. Optically pumped magnetometers, using vapors of alkaline metals (K or Rb or Cs), which we shall consider, can today achieve the sensitivity of about $10^{-16}$ T (few tens of fT) and their theoretical sensitivity is even better than this of SQUID (superconducting quantum interference device) magnetometer. Magnetometers with vapors of alkaline metals are known since 1957 (Dehmelt[1,2], Bell and Bloom[3], Kastler[4]), however, it was necessary to have a stable tunable diode laser in order to achieve in the last decade the mentioned sensitivity. The principles of the optically pumped magnetometer with potassium (K) atoms vapor will be presented. Followed by the application of such magnetometer in the low frequency RF spectroscopy ($^{14}$N NQR), as well as in quasi DC measurements of stimulated activity of audio cortex.

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# Merjenje in modeliranje linijske paroprepustnosti standardnih sendvič panelov jeklo/MW/jeklo

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Meritev upornosti difuziji vodne pare gradbene komponente/izolacije se običajno izvaja po EN ISO 12572 ali EN 12086. Zaradi omejene velikosti in oblike uporabljanih "šalčk" merjenje velikosti parnih mostov pri transmisiji vodne pare na ta način lahko postane zahtevno. Zato je v predstavljeni študiji uporabljena dvokomorna merilna naprava z rH=0 in 85% v posamezni komori. Dodatno je pri "suhi" komori, podobno kot to že obstaja pri merjenju toplotne prevodnosti po EN 12667, uporabljen še ščit. Merjeni vzorci so 15 cm debeli sendvič paneli iz dveh kovinskih listov na vsaki strani jedra iz goste kamene volne. Dva taka panela se v gradbeni konstrukciji dotikata drug drugega. Skozi njun spoj vodna para (običajno) iz notranjega prostora prehaja navzven. Merili smo paroprepustnost 5 različnih spojev, ki se razlikujejo glede na tip in število uporabljenih tesnil: brez tesnil, z enojnim ali dvojnim tesnilom iz poliuretanske pene teri enojnim ali dvojnim tesnilom iz EPDM gume.
Zaradi počasnega prehajanja vodne pare skozi tako konstrukcijo iz dveh panelov, smo meritve zaustavili veliko prej, preden se je vzpostavilo stacionarno stanje. Asimptotske vrednosti experimentalnih rezultatov smo modelirali. Na podlagi modela smo ob predpostavki popolne parne zapornosti kovinskih lističev definirali in izračunali linijske paroprepustnosti posameznih spojev in upornosti difuziji vodne pare ustreznih konstrukcij.

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# Measuring and modelling of linear water vapour transmittance of steel/MW/steel sandwich panelsl

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Usually measurement of water vapour diffusion resistance factor of building components/insulation is performed according to EN ISO 12572 or EN 12086. Measuring vapour transmission in this way by means of linear water vapour bridges would be difficult because the limited sample size and shape of "cups" used. Therefore in the work presented measurement equipment with twin chambers with rH = 0 and 85 % was used. Additionally a guard around the "dry" chamber, behaving like a guard at the thermal conductivity measurement according to EN 12667, has been used.
Measured samples were 15 cm thick sandwich panels composed of two steel sheets with a dense mineral wool core in-between. Two such panels connect in real building construction. Through their joint water vapour (usually) flows from the inside to the outside. 5 different joints, different in the type and number of used sealants, were measured: joint without a sealant, with one or two PUR-foam and one or two EPDM-rubber sealants.
Due to the slow process of water vapur diffusion through such a construction of two panels, measurements were stopped well before steady state was reached. Asymptotic values of experimental results were modelled. From the model and under assumption of vapour tightness of steel sheets, linear water vapour transmittance of the joints was defined and calculated together with water vapour resistance of the corresponding constructions.

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# Entropija nekaterih konformnih mej med $N = (2, 2)$ sigma modeli

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V limiti neskončnega volumna lahko številne $N = (2, 2)$ dvodimenzionalne nelinearne sigma modele s ciljno mnogoterostjo tipa Calabi Yau opišemo z $N = (2, 2)$ umerjenimi linearnimi sigma modeli. Pred kratkim je bilo pokazano, da dva-sferna particijska funkcija teh ultravioličnih teorij poda eksakten kvantno-popravljen Kählerjev potencial na kvantnem Kählerjevem prostorov modulijev ciljnih prostorov, ki so Calabi Yau tri-mnogoterosti. Natančneje, vrtinčni del dva-sferne particijske funkcije lahko identificiramo z Giventalovo $\mathcal{J}$-funkcijo, kar omogoča izračun Gromov-Witten-ovih invariant genusa nič brez uporabe zrcalne simetrije.

V svojem govoru bom predstavil zgoraj opisano konstrukcijo in njeno posplošitev na $N = (2, 2)$ superkonformne sigma modele z netrivialnimi mejami. Pokazal bom, da je entropija konformnih meja med temi teorijami podana s Calabijevo distasično funkcijo (Calabi's distasis function) in komentiral neperturbativne popravke. Podobno kot v primeru s trivialnimi mejami med $N = (2, 2)$ superkonformnimi teorijami so popravki povezani z dva-sferno particijsko funkcijo relevantnih umerjenih linearnih sigma modelov v prisotnosti $N = 2$ supersimetrijskih domenskih zidov.

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# Entropy of certain conformal interfaces between $N = (2, 2)$ sigma models

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In the large volume limit many $N = (2, 2)$ two-dimensional nonlinear sigma models with Calabi-Yau target spaces are described by $N = (2, 2)$ gauged linear sigma models. It was recently shown that the two-sphere partition function of such ultraviolet theories computes the exact quantum corrected Kähler potential on the quantum Kähler moduli space of the Calabi Yau threefold target spaces. In particular the vortex part of the two-sphere partition function can be identified with Givental's $\mathcal{J}$-function, which allows the computation of genus zero Gromov-Witten invariants without the use of mirror symmetry.

In my talk I will present the above construction and its extension to the analysis of the moduli space of $N = (2, 2)$ superconformal sigma models with non-trivial interfaces. I will show that the entropy of conformal interfaces between these theories is given in terms of the Calabi's distasis function and comment on the nonperturbative corrections to it. Similarly to the non-interface case, they are related to the two-sphere partition function of the corresponding gauged linear sigma models in the presence of $N = 2$ supersymmetric domain walls.

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# Kvazilokalni ohranitveni zakoni iz polcikličnih nerazcepnih upodobitev $U_q(sl_2)$ v verigah $XXZ$ s spinom $1/2$

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Predstavil bom konstrukcijo novih kvazilokalnih ohranjenih količin, porojenih iz polcikličnih upodobitev kvantne grupe $U_q(sl_2)$, v brezvrzelnem režimu ($|\Delta| \leq 1$) Heisenbergove verige $XXZ$, spinov $1/2$. Za omenjene upodobitve je značilno periodično delovanje lestvičnih operatorjev – generatorjev algebre $U_q(sl_2)$. Posledica te periodičnosti je neohranjanje komponente magnetizacije v smeri $z$. Predstavljena bo možnost uporabe v relaksacijski dinamiki po trenutni zlomitvi simetrije $U(1)$.

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# Quasilocal conservation laws from semicyclic irreducible representations of $U_q(sl_2)$ in $XXZ$ spin-$1/2$ chains

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I shal discuss the construction of quasilocal conservation laws in the gapless ($|\Delta| \leq 1$) regime of the Heisenberg $XXZ$ spin-1/2 chain, using semicyclic irreducible representations of $U_q(sl_2)$. These representations are characterized by a periodic action of ladder operators, which act as generators of the aforementioned algebra. As a direct consequence of this periodicity, $z$-magnetization is not conserved by these conserved charges. The possibility of application in relaxation dynamics resulting from $U(1)$-breaking quantum quenches will be discussed.

**References**

[1] L. Zadnik, M. Medenjak, T. Prosen, *Quasilocal conservation laws from semicyclic irreducible representations of $U_q(sl_2)$ in $XXZ$ spin-1/2 chains* (2015), arXiv:1510.08302.

[2] T. Prosen, *Nucl. Phys. B* **886** (2014), 1177.

[3] C. Korff, *J. Phys. A: Math. Gen.* **36** (2003) 5229-5266.

[4] D. Arnaudon, *Fusion rules and R-matrices for representations of $SL(2)_q$ at roots of unity* (1992), arXiv:hep-th/9203011.

[5] E. Ilievski, *Exact solutions of open integrable quantum spin chains* (2014), arXiv:1410.1446v1.

# Kvantna večdelčna lokalizacija

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Sistemi z neredom pogosto kažejo znake lokalizacije. Slavni primer je t.i. Andersonova lokalizacije neinteragirajočih elektronov. Za ta primer se da rigorozno pokazati, da so v eni dimenziji vsa lastna stanja lokalizirana. Model neinteragirajočih elektronov je sicer zelo uporaben, kljub temu pa mora bolj realistični opis pogosto vključiti tudi interakcijo med delci. Naravno vprašanje je, ali lokalizacija preživi v prisotnosti nereda? Pred približno desetimi leti so se pojavili rezultati, ki so nakazovali, da je lokalizacija v prisotnosti interakcij možna – pojav, ki ga imenujemo večdelčna lokalizacija. Še vedno pa smo daleč od popolnega razumevanja, tako da bom podal pregled trenutnega stanja področja.

**Reference**

[1] R. Nandkishore in D. A. Huse, *Annu. Rev. Condens. Matter Phys.* **6** (2015) 15-38.

[2] E. Altman in R. Vosk, *Annu. Rev. Condens. Matter Phys.* **6** (2015) 17.1-17.27.

# Quantum many-body localization

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Systems with disorder frequently show localization. A famous example is the Anderson localization in a system of noninteracting electrons. One can show rigorously that in such a case all eigenstates of a one-dimensional model are localized. Noninteracting electrons, though a very useful model, is often an idealization of a more realistic situation with interaction between particles. A natural question to ask is does localization survive in the presence of interaction? About 10 years ago results appeared, claiming that one can have localization in the presence of interaction – a phenomenon dubbed a many-body localization. The problem though is far from being understood and I will review the present state of knowledge.

**References**

[1] R. Nandkishore and D. A. Huse, *Annu. Rev. Condens. Matter Phys.* **6** (2015) 15-38.

[2] E. Altman and R. Vosk, *Annu. Rev. Condens. Matter Phys.* **6** (2015) 17.1-17.27.

# Nehomogena stanja uniformnih spinskih sistemov

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Nehomogenost v uniformnih elektronskih sistemih je intriganten nov pojav v fiziki kondenzirane materije. Vodi do številnih zanimivih funkcionalnih lastnosti, kot so visokotemperaturna superprevodnost v kupratih, kolosalna magnetoupornost v manganitih in velikanska elektrostrikcija v relaksorjih [1]. Nehomogenost je povezana z več prostostnimi stopnjami, ki med seboj tekmujejo, in v splošnem zahteva aktivno prostostnjo stopnjo naboja. Podoben fenomen pa je moč pričakovati tudi v geometrijsko frustriranih spinskih sistemih z več degeneriranimi fazami, ki med seboj tekmujejo. Najprej bom predstavil vzorčni primer fazne separacije v spinskih sistemih [2]. V antiferomagnetu na trikotni mreži $\alpha$-$NaMnO_2$ smo odkrili intrinzično nehomogeno magneto-strukturno stanje. Primerjava tega sistema z izostrukturno sestrsko spojino $CuMnO_2$, v kateri pa je osnovno stanje precej bolj homogeno [3], nam je omogočila izpostaviti ključno vlogo geometrijske frustracije in skoraj degenerirane kristalne strukture pri stabilizaciji tega nehomogenega stanja. Predstavil bom še naše nedavno odkritje poriodične nehomogenosti – novega moduliranega spinskega vzorca v obliki prog, do katerega pride v sistemu cikcak verig $\beta$-$TeVO_4$ [4]. V tem kontekstu bom predstavil nov mehanizem za formacijo prog, ki bazira na šibki frustrirani izmenjalni interakciji med verigami.

**Reference**

[1] E. Dagotto, *Science* **309** (2005) 257.

[2] A. Zorko, O. Adamopoulos, M. Komelj, D. Arčon, and A. Lappas, *Nature Communications* **5** (2014) 3222.

[3] A. Zorko, J. Kokalj, M. Komelj, O. Adamopoulos, H. Luetkens, D. Arčon, and A. Lappas, *Scientific Reports* **5** (2015) 9272.

[4] M. Pregelj, A. Zorko, O. Zaharko, H. Nojiri, H. Berger, L. C. Chapon, and D. Arčon, *Nature Communications* **6** (2015) 7255.

# Inhomogeneous states of uniform spin systems

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Electronic inhomogeneity of uniform systems is an intriguing, emergent phenomenon in condensed matter. It leads to various fascinating functional properties, such as high-$T_c$ superconductivity in cuprates, colossal magnetoresistance in manganites, and giant electrostriction in relaxors [1]. It is related to competing degrees of freedom and in general requires active charge degrees of freedom. However, a similar phenomenon may be expected also in geometrically frustrated spin systems with multiple competing degenerate phases. I will first present a paradigm of phase separation in spin systems [2]. In the triangular-lattice antiferromagnet $\alpha$-$NaMnO_2$ we have found an intrinsically inhomogeneous magnetostructural state. By comparing this system to the isostructural sister compound $CuMnO_2$ that features a much more homogeneous ground state [2], the crucial role of geometrical frustration and near-degenerate crystal structures in stabilizing this unprecedented inhomogeneous ground state will be highlighted. I will also present our recent discovery of a periodic inhomogeneity – a novel spin-stripe textures that develops in the $\beta$-$TeVO_4$ zigzag-chain system [4]. In this context, a novel route for stripe formation that is based on weak frustrated interchain exchange interactions will be discussed.

**References**

[1] E. Dagotto, *Science* **309** (2005) 257.

[2] A. Zorko, O. Adamopoulos, M. Komelj, D. Arčon, and A. Lappas, *Nature Communications* **5** (2014) 3222.

[3] A. Zorko, J. Kokalj, M. Komelj, O. Adamopoulos, H. Luetkens, D. Arčon, and A. Lappas, *Scientific Reports* **5** (2015) 9272.

[4] M. Pregelj, A. Zorko, O. Zaharko, H. Nojiri, H. Berger, L. C. Chapon, and D. Arčon, *Nature Communications* **6** (2015) 7255.

# Topološka mehka snov

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Topološka mehka snov je posebna vrsta kompleksnih mehkih sistemov s stabilnimi defekti v orientacijskem parametru urejenosti. Direktni in medsebojni vplivi geometrije ograditve, površinskega sidranja molekul, zunanjih polj in lastne kiralnosti nematskega media, lahko vodijo v frustracijo in posledično do stabilnih ali metastabilnih disklinacij in solitonskih deformacij urejenosti mehke snovi. V zadnjem obdobju je veliko pozornosti posvečene modrim fazam in nematskim koloidom. V okviru predavanja bom predstavil naše novejše študije, ki so rezultat tesne sklopitve teorije, numeričnih simulacij in eksperimentalnih študij izbranih topoloških mehkih snovi: i) zaznava skirmionske strukture v tankih plasteh modrih faz, ii) koloidni delci dekorirani s singularnimi in solitonskimi deformacijami [1-4] in iii) oblikovani in preoblikovanja zmožni koloidni delci v nematiku [5].

**Reference**

[1] 1. T. Porenta, S. Čopar, P. J. Ackerman, M. B. Pandey, M. C. M. Varney, I. I. Smalyukh and S. Žumer, *Scientific Reports* **4** (2014) 7337.

[2] 2. M. Nikkhou, M. Škarabot, S. Čopar, M. Ravnik, S. Žumer and I. Muševič, *Nature Physics* **11** (2015) 183.

[3] 3. A. Martinez, M. Ravnik, B. Lucero, R. Visvanathan, S. Žumer, and I. I. Smalyukh, *Nature Materials* **13** (2014) 258.

[4] 4. S. Čopar, U. Tkalec, I. Muševič and S. Žumer, *PNAS* **112** (2015) 1675.

[5] 5. J. Dontabhaktuni, M. Ravnik and S. Žumer, *PNAS* **111** (2014) 2464.

# Topological soft matter

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Topological soft matter is a kind of complex soft systems with stable defects in the orientational order-parameter field. Effects of confining geometry, anchoring, external fields, chirality and their interplay in nematogenic liquid crystals may lead to frustration and consequently to stable or metastable disclinations and solitonic deformations. Recently a lot of attention has been devoted to confined blue phases and colloidal nematics. Here I present an overview of our recent achievements based on synergy of numerical modeling, theory and experiments devoted to chosen examples of topological soft matter: i) detection of skyrmion lattices in confined blue phases, ii) colloidal particles dressed with singular and solitonic deformations [1-4], and iii) shaped & shapeable colloidal particles in nematics [5].

**References**

[1] 1. T. Porenta, S. Čopar, P. J. Ackerman, M. B. Pandey, M. C. M. Varney, I. I. Smalyukh and S. Žumer, *Scientific Reports* **4** (2014) 7337.

[2] 2. M. Nikkhou, M. Škarabot, S. Čopar, M. Ravnik, S. Žumer and I. Muševič, *Nature Physics* **11** (2015) 183.

[3] 3. A. Martinez, M. Ravnik, B. Lucero, R. Visvanathan, S. Žumer, and I. I. Smalyukh, *Nature Materials* **13** (2014) 258.

[4] 4. S. Čopar, U. Tkalec, I. Muševič and S. Žumer, *PNAS* **112** (2015) 1675.

[5] 5. J. Dontabhaktuni, M. Ravnik and S. Žumer, *PNAS* **111** (2014) 2464.

**1. Koncert / 1st Concert**
**10.12.2015 (19:00) Art Kavarna, Hotel Piramida**

**BARBARA UPELJ - violina (violin)**
**URŠKA OREŠIČ ŠANTAVEC - klavir, vokal (piano, vocal)**

**Program:**

J. S. Bach: AIR (from the Suite in D-major)

P. de Sarasasate: SERENATA ANDALUZA (from Dances Espagnoles, op. 22)

V. Monti: CZARDAS

J. Strauss: ABSCHIEDS - WALZER

A. Rubinstein: ROMANCE

U. Orešič Š., F. Lainšček: NAJINO NEBO (DRUGI BREG ŽELJA) (OUR SKY)

U. Orešič Š., F. Lainšček: EJ, SREČA MOJA (EY, LUCKY ME)

U. Orešič Š., F. Lainšček: KAKO SEM JAZ (HOW WAS ME)

U. Orešič Š., F. Lainšček: NE VRAČAJ SE (DON'T RETURN)

A. Jay Lerner, F. Loewe: WOULDN'T IT BE LOVERLY (from My Fair Lady)

A.L.Webber: I DREAMED A DREAM (from Miserables)

**Barbara Upelj M. M.** se je rodila v Mariboru, Slovenija. S 16 leti je bila sprejeta na Akademijo za glasbo v Ljubljani, kjer je študirala violino v razredu red. Prof. Roka Klopčiča. Leta 2006 je diplomirala z odliko in bila sprejeta na podiplomski magistrski študij na "University of Texas at Austin", kjer je študitrala v razredu Dr. Eugena Gratovicha. Študij je uspešno zaključila maja 2008, prejela pa je tudi priznanje univerze za izjemen magistrski recital. Barbara je nastopala na festivalih po Evropi (Sant Petersburg, Burgos, Viana do Castelo) in v Texasu (Austin). Bila je ena prvih članov Austin Pops, vodilnega austinskega orkestra za popularno glasbo. V času svojega študija na UT v Austinu je bila članica String Project-a, organizacije za poučevanje godal ter asistentka Dr. Eugena Gratovicha. Po vrnitvi v Slovenijo se je zaposlila kot učiteljica violine na Ptuju in v Gornji Radgoni, delovala pa je tudi kot samostojna in komorna glasbenica. Leta 2009 je na Ptuju organizirala prvi festival Glasba v Kloštru, ki je imel velik odziv in je postal del ptujskega kulturnega dogajanja. Je soustanoviteljica Dua Fla-Via, sodeluje pa z najrazličnešimi zasedbami, kot so Simbolični orkester, Terrafolk, Avven in drugi. Leta 2013 se je z družino preselila v Graz, Avstrija, kjer deluje kot samostojna glasbenica. Je članica Graškega Salonskega orkestra, Graške Filharmonije, kvarteta Allegra in mnogih drugih zasedb.

**Barbara Upelj M. M.** was born in Maribor, Slovenia. With 16 years of age, she was accepted to the Academy of Music in Ljubljana, where she studied violin with professor Rok Klopcic. She graduated with top marks and was accepted to a postgraduate program at The University of Texas at Austin, Texas, where she studied with Dr. Eugene Gratovich. She completed her studies in the field of Music Performance with honors in May 2008. She performed at music festivals in Europe (Saint Petersburg, Russia; Burgos, Spain; Viana do Castelo, Portugal) and the USA (Austin, Texas). In 2008, she was honored by the University of Texas at Austin for an outstanding masters recital. She was one of the first members of Austin Pops, the leading Austin orchestra for popular music. During her time at the UT at Austin she was a member of String Project, an organization for educating children in string instruments, and Dr. Eugene Gratovich′s teaching assistant. After returning to Slovenija, she worked as a teacher in Ptuj and Gornja Radgona and as a solo and chamber musician. In summer of 2009 she organized the festival Music in the monastery in Ptuj, which had a great response and has been an important part of Ptuj′s cultural life ever since. She is a co-founder of Duo Fla-Via. Her musical engagements also include Symbolic Orchestra, Terrafolk, rock group Avven, the A la Fetish project and many other classical and non-classical projects. In 2013 she moved to Graz, Austria. Currently she is active as a solo and chamber musician in Graz, Austria, as a member of Graz Salon Orchestra, Graz Philharmonic Orchestra and many other chamber groups.

**Mag. Urška Orešič Šantavec** (rojena 1981 v Mariboru) je leta 2005 z odliko diplomirala iz študija kompozicije in glasbene teorije na Akademiji za glasbo v Ljubljani (mentor prof. Pavel Mihelčič), leta 2009 iz klavirja (mentor prof. Andrej Jarc), 2011 pa zaključila še podiplomski magistrski študij iz glasbene teorije (mentor prof. Pavel Mihelčič). V času študija kompozicije je bila Zoisova štipendistka; za svoje komorne skladbe, ki jih je predstavila na dveh avtorskih večerih, je leta 2005 prejela študentsko Prešernovo nagrado. Njen skladateljski opus obsega solistična, zborovska, komorna, orkestralna dela in opero klasičnih zvrsti ter tudi dela za pihalni orkester, big band in druge zasedbe lahkotnejših zvrsti. Urška Orešič deluje kot skladateljica, aranžerka, pianistka, korepetitorka in pevka stilno različnih glasbenih zvrsti. Sodeluje s priznanimi slovenskimi glasbeniki, nastopa na tudi na samostojnih koncertih, protokolarnih in drugih prireditvah po državi. Zaposlena je kot profesorica glasbeno-teoretskih predmetov in klavirja na 1. gimnaziji v Celju, zadnji dve leti pa tudi kot asistentka iz področja glasbene teorije na Pedagoški fakulteti v Mariboru.

**Mag. Urška Orešič Šantavec** (born 1981 in Maribor, Slovenia) graduated with honors at the Academy of Music; in 2005, in the field of Composition and Music Theory (supervisor prof. Mihelčič Pavel), in 2009 in Piano performance (supervisor prof. Andrej Jarc), and in 2011 she completed her postgraduate Masters studies in Music theory. During her studies at the Academy of Music, she presented her chamber music on two composition recitals, and in 2005 she was awarded Prešeren Prize by the Academy of Music. She was also a recipient of Zois Scholarship. Her musical opus includes different soloistic, choral, chamber and orchestral works in classical genre, as well as works for wind orchestra, Big Band and other groups of jazz and popular music genre. Uršska Orešič Šantavec is active as a composer, arranger, pianist, accompanist and singer of various genres of music. She collaborates with renowned Slovenian musicians as a professional events and protocol protagonist. She teaches Sofeggio and Harmony at Gymnasium of Art in Celje and is an assistent of Music Theory at Faculty of Pedagogic in Maribor.

**2. Koncert / 2nd Concert**
**11.12.2015 (19:00) Art Kavarna, Hotel Piramida**

**DOROTEA SENICA - flavta (flute)**
**IVAN FERČIČ - klavir (piano)**

**Program:**

W. A. Mozart: Rondo v D-duru, KV 373

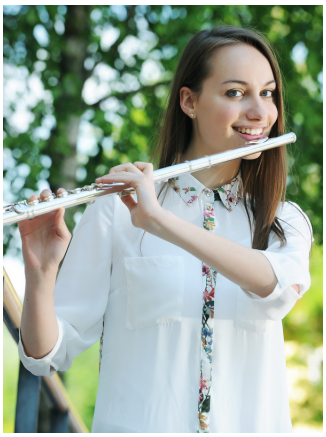
C.P. Taffanel: Fantazija na teme iz opere Čarostrelec

C. Reinecke: Koncert za flavto in orkester v D-duru op.283

- Allegro molto moderato
- Lento e mesto
- Finale

L. Liebermann: Sonata za flavto in klavir, op. 23

- Lento con rubato
- Presto energico



**Dorotea Senica** (rojena 1997) je začela igrati prečno flavto z osmimi leti na Konservatoriju Maribor pri profesorici Valeriji Kamplet. S 15. leti je opravila sprejemni izpit na redni študij koncertne smeri flavta na Univerzi Mozarteum v Salzburgu, kjer je študentka v razredu univ. prof. Michaela Martina Koflerja. Osvojila je mnogo prvih nagrad (prvih mest) na državnih in mednarodnih tekmovanjih: prve nagrade na TEMSIGU (flavta 2010, 2013, trio flavt 2012), Ars nova Trst - flavta in zmagovalka vseh kategorij (2007), zmagovalka s triom - flavta, klarinet, klavir (2011), prva nagrada na mednarodnem EMCY tekmovanju Petar Konjovi v Beogradu (2013), dve zmagi in Laureat v Požarevcu ( 2010, 2013), zmaga na mednarodnem tekmovanju Woodwind & Brass Varaždin (2015), prvo mesto na mednarodnem tekmovanju Citta di Padova (2011). Dorotei se je leta 2010 kot edini Slovenki doslej uspelo uvrstiti na zelo zahtevno 3-etapno rusko mednarodno Rotary tekmovanje nadarjenih mladih glasbenikov do 12 let v Moskvi, kjer se zahteva program maturitetne težavnostne stopnje. Kot 17-letna se je leta 2014 uvrstila na mednarodno solistično tekmovanje mladih do 32 let s simfoničnim pihalnim orkestrom Intermusica Birkfeld. V Kazinski dvorani SNG Maribor je dvakrat igrala kot solistka z godalnim orkestrom Konservatorija za glasbo in balet Maribor (2010 in 2013). V Viteški dvorani Mariborskega gradu je nastopila z godalnim kvartetom Feguš (2013). Dvakrat je imela celovečerni recital v dvorani Union v okviru Festivala Lent, Salon glasbenih umetnikov v Mariboru (2013 in 2015). V okviru Glasbene mladine Ljubljanske je imela polovico recitala v Rdeči dvorani Magistrata s pianistom Ivanom Ferčičem (2014). Za izjemne dosežke je že ob zaključku nižje glasbene šole dobila najvišje priznanje Konservatorija za glasbo in balet Maribor Dr. Roman Klasinc (2010). Dorotea se izpopolnjuje na poletnih šolah pri profesorjih Mateju Zupanu, Mileni Lipovšek in Lizi Hawlina Prešiček, Michaelu Martinu Koflerju, Martinu Beliču, Erwinu Klambauerju ter na seminarjih pri Jamesu Galwayu, Karl-Heinz Schtzu, Julienu Beaudimentu, Juliette Hurel, Bulent Evcilu, Janosu Balintu, Alešu Kacjanu in Mateji Bajt. Dorotea je prejemnica Zoisove štipendije ter Gallusova varovanka.

**Dorotea Senica** was born on 8th September 1997 in Frankfurt/Main (Germany). She started playing flute when she was eight years old by professor Valerija Kamplet at the Conservatory for Music and Ballet Maribor (Slovenia). When she was 16, she became a student on University Mozarteum in Salzburg by professor Michael Martin Kofler. She won many times the 1st place and the 1st prize at national and international competitions: Slovenian National Music Completion TEMSIG (flute 2010, 2013, flute trio 2012), Ars Nova Trieste flute- winner of all categories (2007) international EMCY Competition Petar Konjovi in Belgrade (2010), two times international competition for woodwind in Požarevac (2007 and 2010), Varaždin Woodwind & Brass (2015), Citta di Padova (2011). In the year 2010, she became the first Slovenian who attended a 3-level Russian Rotary competition for young and talented musicians till age of 12 in Moscow. As a 17 year old Dorotea was ranked in the international competition of young soloist till age 32 playing with a woodwind & brass symphony orchestra Intermusica Birkfeld. In the Casino Hall of the Slovenian National Theatre Maribor, she played solo flute with the string orchestra of Conservatory for Music and Ballet Maribor (2010, 2013). With the string quartet Feguš, she performed in the Knight Hall of the Maribor Castle (2013). In scope of the Salon of Music Artists at the Lent festival, Dorotea performed in years 2013 and 2015 a recital in Maribor Union Hall. She shared a recital in Ljubljana within the framework of the Musical Youth Organization of Ljubljana in the Red Chamber Hall of Magistrat playing with a pianist Ivan Ferčič (2014). For outstanding achievements of arts, Dorotea received the highest award of the Conservatory of Music and Ballet Maribor, the degree "Dr. Roman Klasinc (2010). Dorotea is perfecting her knowledge at summer schools for flute with well known musicians and professors: Michael Martin Kofler, Matej Zupan, Karolina Šantl Zupan, Martin Belič, Erwin Klambauer, Milena Lipovšek, Lizi Hawlina Prešiček and Lisette da Silva as well in the seminars with James Galway, Bulent Evcil, Karl-Heinz Schutz, Julien Beaudiment, Janos Balint, Juliette Hurel, Aleš Kacjan and Mateja Bajt.

Koncertni pianist in akordeonist **Ivan Ferčič** je glasbeno izobraževanje začel na glasbeni šoli v Mariboru na oddelkih za klavir in harmoniko ter ga nadaljeval na Umetniški gimnaziji pri prof. Narcisu Grabarju in Sijavušu Gadžijevu (klavir, sedanji Konservatorij za glasbo v Ljubljani) ter Slavku Magdiu (harmonika). Leta 2003 je ob zaključku Umetniške gimnazije prejel diplomo dr. Romana Klasinca za izjemne umetniške dosežke. Istega leta je bil sprejet na Akademijo za glasbo v Ljubljani, kjer je leta 2008 v razredu red. prof. Tatjane Ognjanovič z odliko diplomiral (diploma summa cum laude). Udeležil se je mednarodnih klavirskih šol pri prof. A. Valdmi, S. Gadžijevu, N. Floresu, M. Hughesu, J. Jandu, J. G. Jiračku in G. Wallischu. Javno je nastopal kot solist in v komornih skupinah po Sloveniji, na Hrvaškem, v Avstriji in Italiji, Makedoniji, na Češkem in v Veliki Britaniji ter na domačih ter tujih festivalih (tudi v okviru Evropske prestolnice kulture Maribor 2012). Snemal je tudi za Radio Slovenija. Kot solist je nastopil z Mladinskim komornim orkestrom Maribor (čembalo), igral z Mariborsko filharmonijo, Orkestrom RTV Slovenija, festivalskim orkestrom iz Marburga, pa tudi s Slovensko filharmonijo, kasneje še kot občasni član orkestra. Prejel je Prešernovo nagrado Akademije za glasbo v Ljubljani. V šolskem letu 2009/10 je končal podiplomski specialistični študij v razredu prof. Tatjane Ognjanovič ter nato nastopil s Chopinovo drugo sonato na mednarodni konferenci Evropskega združenja klavirskih pedagogov v Ljubljani. Tako je bil povabljen v Cardiff, prestolnico Walesa, kjer je imel recital v okviru tamkajšnje EPTE ter prav tako v Salzburg. - V času šolanja se je udeležil nekaj mednarodnih in večine državnih tekmovanj. Prejel je več zlatih plaket, dosegel eno prvo in štiri druga mesta. Marca 2007 je na državnem tekmovanju v disciplini klavir v najvišji kategoriji IIIb prejel zlato plaketo in prvo nagrado. Tako je tudi zastopal državo Slovenijo na prvem mednarodnem tekmovanju pianistov iz vseh članic Evropske Unije v organizaciji klavirskih pedagogov EPTA, ki se je odvilo konec junija 2009 v Pragi. Prejel je častno diplomo za izjemno interpretacijo Slik z razstave Modesta Musorgskega. Trenutno deluje na Konservatoriju za glasbo in balet Maribor.

**Ivan Ferčič** (1984) began his musical education at the Elementary Music School in Maribor and continued at The High School of Music and Ballet in Maribor (Slavko Magdi, accordion, Narcis Grabar and Sijavuš Gadžijev, piano). As he graduated from The High School of Music and Ballet in 2003, he received a Roman Klasinc Award for the outstanding artistic achievements. At the same year, he was admitted to study piano at the Academy of Music in Ljubljana with Professor Tatjana Ognjanovič. During his studies, he was awarded several gold awards and was a winner of four second prizes at national and international competitions (piano and accordion). In March 2007, he won a gold award and first prize for the highest category at the national competition. Therefore, he represented Slovenia at the first international piano competition of EU, organized by EPTA in Prague in June 2009. There he received Special prize of the jury for Mussorgsky's Pictures from exhibition. He has participated at several international master classes with noted pedagogues and pianists such as Professors A. Valdma, S. Gadžijev, N. Flores, M. Hughes, J. Janda, J. G. Jiraček in G. Wallisch. He has played as a soloist and chamber musicians (accordion and piano) in Slovenia, Croatia, Austria (Salzburg baroque museum), Italy, Macedonia, Czech Republic and United Kingdom. He has also recorded for the Radio of Slovenia. As a soloist he played with the Maribor Youth Chamber Orchestra (harpsichord), twice with the Slovenian Philharmonic (later also as the periodic member of the orchestra), Slovenian RTV Orchestra and Maribor Philharmonic. In 2007, he received the highest award from the Academy of Music, University of Ljubljana, Slovenia, the Prešeren Award. He graduated with summa cum laude in May 2008. In the academic year 2009/10, he finished his postgraduate study in the class of Professor Tatjana Ognjanovič. Later, he was chosen to participate on the international conference of EPTA, where he played Chopins second sonata. There he was invited by the members of British EPTA to play on their conference in Cardiff, the capital of Wales. He is currently employed on Conservatorium for music Maribor.

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