National Academy of Sciences of Ukraine
Bogolyubov Institute for Theoretical Physics

Bogolyubov Conference

Problems of Theoretical Physics

dedicated to the 50th anniversary of the
Bogolyubov Institute for Theoretical Physics of the NAS of Ukraine

May 24 – 26, 2016

Kyiv, Ukraine

Program & Abstracts

Kyiv 2016

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Tuesday, May 24, 2016

9:00	**Registration**
10:00	**Opening** **Anatoly G. Zagorodny**, *Bogolyubov Institute for Theoretical Physics*

Morning Session
Chair: Anatoly G. Zagorodny

10:10 O.1	**Hiroshi Yokoyama** A piece of hindsight about the surface-like elastic constant K13 in nematic liquid crystals: How the reality overrules the symmetry *Kent State University, USA*
10:50 O.2	**Nikolai F. Shul'ga** Passing of charged high energy particles through straight and bent crystals *National Science Center "Kharkiv Institute for Physics and Technology"*
11:30 O.3	**Yury V. Slyusarenko** The BBGKY hierarchy and Fokker-Planck equation for many-body dissipative randomly driven systems *National Science Center "Kharkiv Institute for Physics and Technology"*
12:00	**Coffee break**
12:20 O.4	**Alexander Sokolovsky** Nonequilibium Gibbs free energy and phase transition theory *Oles Hohchar Dnipropetrovsk National University*

12:40 O.5	**Mykhailo V. Tokarchuk** BBGKY'S chain of kinetic equations, non-equilibrium statistical operator method and collective variable method in the statistical theory of non-equilibrium liquids *Institute for Condensed Matter Physics*
13:00 O.6	**Yuri Poluektov** A simple model of Bose-Einstein condensation of interacting particles *National Science Center "Kharkiv Institute for Physics and Technology"*
13:20 O.7	**Petro Kostrobij** Surface energy of semi-infinite jellium *Lviv Polytechnic National University*
13:40	**LUNCH**

Afternoon Session (Part I)
Chair: Prof. Y.B. Gaididei

15:00 O.8	**Yuriy V. Skrypnyk** Anderson localization as the outcome of the spectrum rearrangement in impure graphene *Kurdyumov Institute for Metal Physics*
15:20 O.9	**Alexander M. Gabovich** Josephson current between d-wave superconductors with partial gapping of the electron spectrum by charge density waves *Institute of Physics*
15:40 O.10	**Andrij Rovenchak** Emulation of anyons at the bosonic end *Ivan Franko National University of Lviv, Theoretical Physics Department*
16:00 O.11	**Sergiy Lyagushyn** To the problem of correlation properties of light generated in superradiance processes *Oles Honchar Dnipropetrovsk National University*
16:20	**Coffee break**

Afternoon Session (Part II)
Chair: Prof. V.M. Loktev

16:35 O.12	**Yurii Fedorov** The propagation of galactic cosmic rays in the outer heliosphere *Main Astronomic Observatory*
16:55 O.13	**Viktor Gerasimenko** The Boltzmann-Grad asymptotic behavior of observables of hard sphere fluids *Institute of Mathematics*
17:15 O.14	**Andrew Snarskii** Phase transition in parametric visibility graph *NTU "Kyiv Polytechnical Institute"*
17:35 O.15	**Aleksander K. Vidybida** Activity of inhibitory neuron with delayed feedback stimulated with Poisson stream is non-Markov *Bogolyubov Institute for Theoretical Physics*
17:55 O.16	**Leonid M. Christophorov** Apparent allostery as an example of molecular synergetics *Bogolyubov Institute for Theoretical Physics*

Poster Session & Welcome party
18:15–20:00

P.1.	**Danylo A. Dobushovskyi** Anomalous behavior of transport function and density of states for the Falicov-Kimball model with correlated hopping *Institute for Condensed Matter Physics*
P.2.	**Vyacheslav Gorev** On the Grad method in the physics of plasma *Oles Honchar Dnipropetrovsk National University*
P.3.	**Karyna Isaieva** Acoustic black holes with compact horizons in atomic Bose-Einstein condensates *Taras Shevchenko National University of Kyiv, Faculty of Physics*
P.4.	**Aleksei I. Ivanytskyi** Geometrical clusterization in SU(2) gluodynamics and liquid-gas phase transition *Bogolyubov Institute for Theoretical Physics*
P.5.	**Oleksandr Kliushnychenko** Blockade effect and switching of non-equilibrium depletion forces in gas of interacting Brownian particles *Institute of Physics*
P.6.	**Valentina Matskevych** Spectra of collective excitations and Green's functions of quadrupole magnetic and ferrimagnetics *National Science Center "Kharkiv Institute for Physics and Technology"*
P.7	**Bogdan M. Markovych** Generalized diffusion equation in the fractional derivatives in Renyi statistics *Lviv Polytechnic National University*

P.8.	**Anatoliy M. Pavlyuk** Generalization of Chebyshev polynomials and knot invariants *Bogolyubov Institute for Theoretical Physics*
P.9.	**Violetta V. Sagun** Chemical freeze-out irregularities as new signals of quark-gluon plasma formation *Bogolyubov Institute for Theoretical Physics*
P.10.	**Andrii S. Sizhuk** The “quantum” evaluation of absorption coefficient *Taras Shevchenko National University of Kiev, Radiophysics Faculty*
P.11.	**Mykola Sloika** Equilibrium magnetization configurations in permalloy spherical shells *Taras Shevchenko National University of Kiev, Radiophysics Faculty*
P.12.	**Oleksii Volkov** Mesoscopic Dzyaloshinskii-Moriya interaction *Bogolyubov Institute for Theoretical Physics*

Wednesday, May 25, 2016

Morning Session (part I)
Chair: Prof. Y.V. Slyusarenko

09:30 O.17	**Ihor V. Stasyuk** Phonon-like excitations and modulational instability in the two-state Bose-Hubbard model *Institute for Condensed Matter Physics*
10:10 O.18	**Yaroslaw Bazaliy** Circular electric currents generated by pure spin current injection *University of South Carolina, Columbia SC, USA*
10:40 O.19	**Alexei Kolezhuk** Magnetic states of ultracold spinor atoms *Taras Shevchenko National University of Kyiv, Institute of High Technologies*
11:10 O.20	**Kostiantyn Yershov** Curvature induced domain wall pinning at a local wire bend *Bogolyubov Institute for Theoretical Physics*
11:30 O.21	**Anton Glushchenko** Classification of degenerate equilibrium states of magnets with spin s=1 *National Science Center "Kharkiv Institute for Physics and Technology"*
11:50 O.22	**Oleksandr V. Pylypovskyi** Structure and dynamics of domain walls in magnetic helices under the action of the Rashba torque *Taras Shevchenko National University of Kyiv*

12:10 **Coffee break**

Morning Session (part II)
Chair: Prof. I.V. Stasyuk

12:20 O.23	**Ernst Pashitskii** The Big Bang as a result of the first-order phase transition driven by changing scalar curvature in expanding early Universe *Institute of Physics*
12:50 O.24	**Vadim V. Kuzmichev** Comparative description of the evolving universe in classical and quantum geometrodynamics *Bogolyubov Institute for Theoretical Physics*
13:10 O.25	**Kyrill Bugaev** New signals of observing two phase transitions in nucleus-nucleus collisions *Bogolyubov Institute for Theoretical Physics*
13:30 O.26	**Dmytro V. Uvarov** Spinor description and integral on-shell representation for curvatures of ***D=5*** gauge fields *National Science Center "Kharkiv Institute for Physics and Technology"*
13:50 O.27	**Dmytro V. Anchishkin** Lattice QCD and hadron resonance gas equation of state *Bogolyubov Institute for Theoretical Physics*

14:10 **LUNCH**

Afternoon Session
Chair: Dr. Y.M. Sinyukov

15:20 O.28	**Andrij M. Shvaika** Nonequilibrium response of a charge density wave ordered insulator *Institute for Condensed Matter Physics*
15:40 O.29	**Julia Seti** Electron-phonon interaction in cascades of nano-devices *Chernivtsi National University, Department of Theoretical Physics*
16:00 O.30	**Volodymyr N. Ermakov** Thermoelectric properties of a conducting molecule from resonant-tunneling calculations *Bogolyubov Institute for Theoretical Physics*
16:20 O.31	**Volodymyr Simulik** Relativistic wave equations of arbitrary spin in quantum mechanics and field theory *Institute of Electron Physics*
16:40	**Coffee break**
16:50 O.32	**Yulia Lashko** Impact of cluster polarization on spectrum of ^{10}Be *Bogolyubov Institute for Theoretical Physics*
17:10 O.33	**Andrij R. Kuzmak** Geometry and entanglement of a two-spin quantum state *Ivan Franko National University of Lviv*
17:30 O.34	**Yuriy A. Mishchenko** Deformed oscillator realization of composite fermions vs composite bosons, and some applications *Bogolyubov Institute for Theoretical Physics*

17:50	**Viktor V. Vasilevsky**
O.35	Systematic investigation of the Hoyle-analogue states in light nuclei *Bogolyubov Institute for Theoretical Physics*
18:10	**Boris Y. Grinyuk**
O.36	Structure of ^{14}C and ^{14}O nuclei within a five-cluster model *Bogolyubov Institute for Theoretical Physics*

Thursday, May 26, 2016

Morning Session
Chair: Prof. A.V. Zolotaryuk

9:30	**Valentyn G. Peschansky**
O.37	Electron Transport in Layered Conductors under Lifshits topological transition *Verkin Institute for Low Temperature Physic & Engineering*
10:00	**Volodymyr Pastukhov**
O.38	Ground-state properties of dipolar Bose mixtures *Ivan Franko National University of Lviv, Theoretical Physics Department*
10:20	**Oleg I. Gerasymov**
O.39	Multiscale analysis of impulse transmission in nonhomogeneous low-dimensional systems *Odesa State Environmental University*
10:40	**Coffee break**
11:00	**Oleksiy O. Vakhnenko**
O.40	Integrable nonlinear Schrödinger system on a ribbon of triangular lattice *Bogolyubov Institute for Theoretical Physics*
11:20	**Nikolai Iorgov**
O.41	Conformal field theory and isomonodromic deformations *Bogolyubov Institute for Theoretical Physics*
11:40	**Oleksii Bystrenko**
O.42	Anomalous diffusion in CTRW lattice model and in irregular potential landscapes. A molecular dynamics study. *Bogolyubov Institute for Theoretical Physics*
12:00	**Alexei L. Rebenko**
O.43	On phase transitions in continuum systems: cell gas model. *Institute for Mathematics*
12:20	**CONFERENCE CLOSING**

CONTENTS

ORAL TALKS

Lattice QCD and hadron resonance gas equation of state

D. Anchishkin[1], V. Vovchenko[1,2], and M. Gorenstein[1,2]

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The Monte Carlo results in lattice QCD for the pressure and energy density at small temperature $T \leq 155$ MeV and zero baryonic chemical potential are analyzed within the hadron resonance gas model. Two extensions of the ideal hadron resonance gas are considered: the excluded volume model which describes a repulsion of hadrons at short distances and Hagedorn model with the exponential mass spectrum. Considering both of these models one by one we do not find the conclusive evidences in favor of any of them. The controversial results appear because of rather different sensitivities of the pressure and energy density to both excluded volume and Hagedorn mass spectrum effects. On the other hand, we have found a clear evidence for a simultaneous presence of both of them. They lead to rather essential contributions: suppression effects for thermodynamical functions of the hadron resonance gas due to the excluded volume effects and enhancement due to the Hagedorn mass spectrum.

[1] D. Anchishkin, V. Vovchenko, J. Phys. G. **42**, 105102 (2015).
[2] V. Vovchenko, D. Anchishkin, M. Gorenstein, Phys. Rev. C. **91**, 024905 (2015).

Circular electric currents generated by pure spin current injection

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We show that local injection of pure spin current can produce electric currents running inside an electrically disconnected device with ferromagnetic and normal metal parts. These currents are circular, run along closed loops inside the device, and are powered by the outside source responsible for spin injection.

Pure spin current injection is always assumed to be special because electric and spin currents are dissociated in such an experiment. Generation of circular currents violates this assumption, and may lead to important consequences. For example, in the non-local voltage measurements of Johnson-Silsbee type it is generally assumed that the absence of electric current is an important advantage that makes measured voltages largely independent of the contact positions and device geometry. We show that circular currents change measured voltages by an amount that has the same order as the voltage magnitude in zero-current situation.

New signals of observing two phase transitions in nucleus-nucleus collisions

K.A. Bugaev[1], **A.I. Ivanytskyi**[1] **V.V. Sagun**[1], **G.M. Zinovjev**[1], **D.R. Oliinychenko**[1,2], **D.H. Rischke**[2]

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Using the most advanced version of the hadron resonance gas model we have found several remarkable irregularities at chemical freeze-out. The most prominent of them are two sets of highly correlated quasi-plateaus in the collision energy dependence of the entropy per baryon, total pion number per baryon, and thermal pion number per baryon which we found at center of mass energies 3.8-4.9 GeV and 7.6-10 GeV [1]. It is striking that each of these sets of plateaus is accompanied by a sharp peak of dimensionless trace anomaly, which in the lattice formulation of QCD is considered as indicator of phase transformation. The low energy set of quasi-plateaus was predicted a long time ago [2] as a signal of quark-gluon-hadron mixed phase formation. The question is whether the high energy correlated quasi-plateaus are also related to some kind of phase transformation. To answer this question we suggest a meta-analysis of the quality description of data (QDD) of 10 existing event generators of nucleus-nucleus collisions using their results in the range of center of mass collision energies from 2.1 GeV to 17.3 GeV. We analyze the mean deviation squared per number of experimental points obtained by these event generators, i.e. the QDD. These generators and their QDD are divided into two groups. The first group includes the generators which account for the quark-gluon plasma formation during nuclear collisions (QGP models), while the second group includes the generators which do not assume the QGP formation in such collisions (hadron gas models). Comparing the QDD of more than a hundred of different data sets of strange hadrons by two groups of models, we found two regions of the equal QDD which are located at the center of mass collision energies 4.4-4.87 GeV and 10.8-12 GeV. At the collision energies between 5 GeV and 10.8 GeV and above 12 GeV we found that QGP models describe data essentially better than the hadron gas ones and, hence, these regions we associate with QGP. On the other hand, the collision energy regions 4.4-4.87 GeV and 10.8-12 GeV we interpret as the energies of two phase transformations between hadron matter and QGP.

[1] K.A. Bugaev et al., Phys. Part. Nucl. Lett. **12**, 238 (2015).
[2] K.A. Bugaev, M.I. Gorenstein and D.H. Rischke, Phys. Lett. B **255**, 18 (1991).
[3] K.A. Bugaev et al., arXiv:1511.06698 [nucl-th] (2015) 11 p.

Anomalous diffusion in CTRW lattice model and in irregular potential landscapes. A molecular dynamics study

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We perform computer simulations of the diffusion process in the continuous time random walk (CTRW) model [1] and in steady randomly shaped potential fields. The simulations based on the CTRW model were carried out in the spirit of molecular dynamics on a lattice with waiting time distribution fixed over the lattice sites. The results of simulations reproduce the general theoretical behavior of mean square displacement as proportional to the fractional power of time. At the same time, the striking finding is the distinct difference between the theoretical numbers for power index and those observed in relevant simulations. On the basis of the results obtained, we propose a model for anomalous diffusion in complex media (e.g., in polymer solutions [2]) based on the generalization of CTRW model to the classical Brownian dynamics (BD) in fixed irregular potential landscape. The results of BD simulations performed for a number of random potentials support this approach (Fig. 1). The most important conclusion is that the fractional sub-diffusion observed in numerical experiments is the result of classical BD, with no need to employ non-conventional stochastic forces and friction to describe the memory effects.

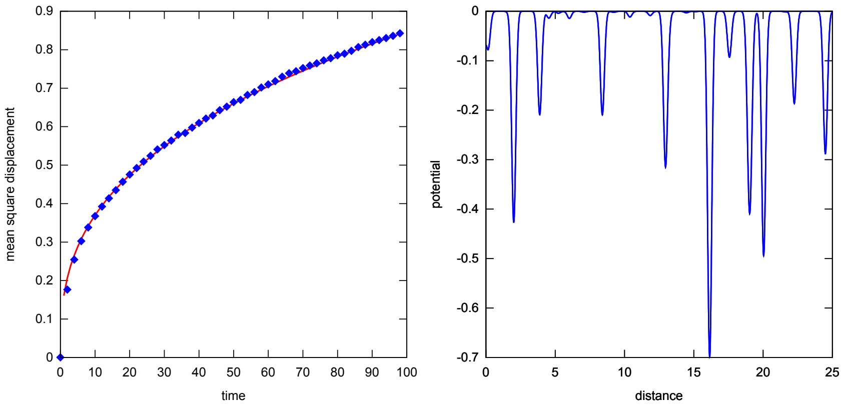

Figure 1 Mean square displacement vs. time for BD simulations (left) with the random potential given on the right. Dots in blue: results of simulations; solid line in red: exact dependence t^s with s=0.36.

[1] R. Metzler, J. Klafter. Phys. Rep. **339**, 1 (2000).
[2] Daniel S. Banks and Cecile Fradin. Biophys. J. **89**, 2960 (2005).

Apparent allostery as an example of molecular synergetics

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Allostery of enzymes is one of the main tools of biological regulation at the molecular level. It implies an ability to transmit the influence of an elementary act of a biochemical reaction – such as the binding of a ligand/substrate at one active centre – upon the binding properties of another, spatially separated active centre, by means of structural (conformational) changes. This ensures, in particular, the so-called cooperativity of enzymes, leading to sigmoid dependencies of the reaction efficiency on substrate concentration.

For decades, realization of such regulatory mechanism in nature was thought as inseparably linked with the necessity of the enzyme to be oligomeric, that is, to have several functional units with their ability to undergo conformational transitions between states of different affinity.

Recently, however, it has been experimentally confirmed that there exist enzymes with the only binding site but nevertheless showing "allosteric" regulation properties; the latter, moreover, are of great physiological importance [1, 2]. In the absence of the spatial aspect of allostery, here the temporal aspect caused by structural memory and protein relaxation rates should obviously come to the fore (cf. [3, 4]). We show how this can be incorporated into a rather universal and simple mechanism based on the explicit account of the process nonequilibricity and corresponding self-organization phenomena within even a single binding site. Such apparent allostery may turn out to be even more common than the classical one. It also provides more convenient means to modify regulatory abilities of enzymes. Indicative manifestations of this kind of allosteric behaviour in statistical characteristics of single-molecule enzymatic reactions [5] are also discussed.

[1] A.C. Whittington et al, PNAS USA **112**, 11553 (2015).
[2] V.J. Hisler et al, PNAS USA **112**, 11430 (2015).
[3] L.N. Christophorov, V.N. Kharkyanen, Chem. Phys. **319**, 330 (2005).
[4] L.N. Christophorov, Springer Proc. Phys. **156**, 223 (2015).
[5] L.N. Christophorov et al, Chem. Phys. Lett. **583**, 170 (2013).

Thermoelectric properties of a conducting molecule from resonant-tunneling calculations

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In the present report, we develop a nonequilibrium description of the stationary thermotransport through a double barrier nanostructure, using the idea of resonant tunneling. The model is rather simple, but can be solved analytically [1], and the theoretical results can be directly compared with experimental data [2]. The result is shown in Fig1. In our calculations, we fixed the parameters by

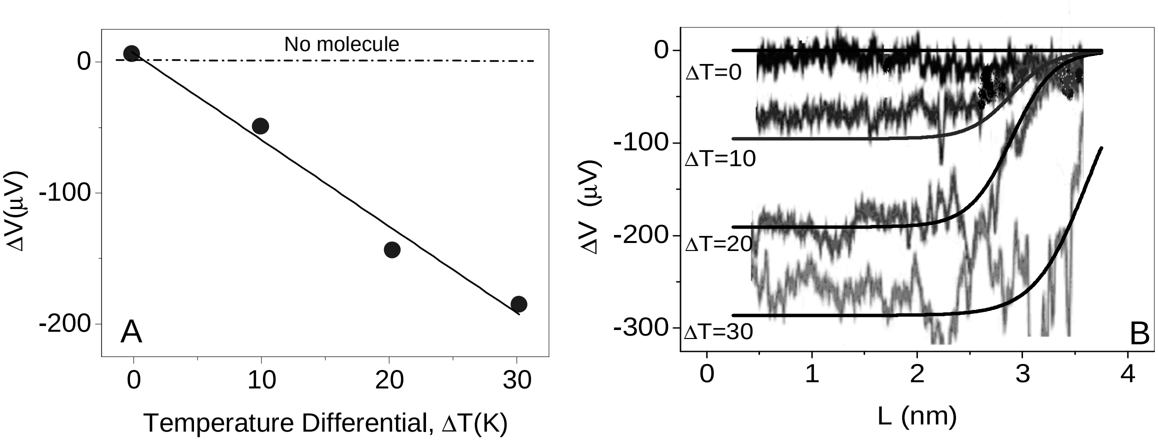

Figure 1 A. Comparison of experiment and theory is demonstrated. B. Dependence of thermovoltage on the distance between electrodes at different temperatures.

obtaining the best fit for $\Delta T = 20$ K. The remaining curves for the other temperatures were then calculated using these parameters. It turns out that the sign of the thermovoltage under resonant tunneling conditions depends sensitively on the participating molecular orbital, and one finds a sign change when the transport channel switches from the highest occupied molecular orbital to the lowest unoccupied molecular orbital. Problem of chemical potentials is resolved. Comparing our results to recent experimental data obtained for a BDT molecule contacted with an STM tip, we observe good agreement.

[1] P. Reddy, et al., Science **315**, 1568 (2007).
[2] V.N. Ermakov, et al, Phys. Rev. B. **92**, 155431 (2015).

The propagation of galactic cosmic rays in the outer heliosphere

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The heliospheric modulation of galactic cosmic rays is studied on the basis of transport equation describing the propagation of charged energetic particles in turbulent magnetic fields. It is supposed that the velocity of supersonic solar wind is radial and constant up to heliospheric termination shock. After termination shock crossing the valocity of solar wind plasma decreases with heliocentric distance up to heliopause. The unmodulated galactic cosmic ray spectrum occurs only great distance away from the heliosphere. Starting from the solution of cosmic ray transport equation the spatial distribution, the energetic spectrum and the anisotropy of galactic cosmic rays are calculated in different regions of the heliosphere. The cosmic ray energy flux is estimated and it is shown that this flux is directed out of the Solar system. Thus the population of energetic particles of Galactic origin aquires energy owing to their interuction with a moving solar wind plasma.

Josephson and quasiparticle currents between *d*-wave superconductors with the partial gapping of electron spectrum by charge density waves

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A model elaborated earlier for the competitive coexistence of d-wave superconductivity and charge-density waves (CDWs), the CDW-gapped d-wave superconductor (CDWdS), has been applied to study the Josephson and quasiparticle currents in tunnel junctions containing CDWdSs as electrodes. The model assumes the two-dimensional character of the electron spectrum appropriate to cuprates. The Fermi surface is supposed to be only partially gapped by CDWs. Both unidirectional and checkerboard CDWs are examined. The Josephson current, I, in the ab crystal plane was calculated between two identical CDWdSs or between a CDWdS and a conventional s-wave superconductor. It was shown that the temperature, orientation, and some other dependences of I become so modified by CDWs that the dielectric electron-hole pairing can be identified by measuring the coherent current.

The quasiparticle tunnel current, J, in the c-direction between two identical CDWdSs or between a CDWdS and a normal metal was also calculated. The voltage, V, dependences of the tunnel conductance $G = dJ/dV$ were shown to include a lot of peculiarities reflecting the intertwining of the superconducting and CDW order parameters and a complicated character of the combined gap profile that arises on the Fermi surface. Our theoretically predicted current-voltage characteristics are in agreement with the experimental results obtained for a number of cuprates. Calculations with the scattered values of the system parameters demonstrate that the intrinsic inhomogeneity observed in high-T_c oxides partially smooth off the $G(V)$ peculiarities. The details may be found in Refs. [1,2].

[1] A.M. Gabovich, M.S. Li, H. Szymczak, A.I. Voitenko, Phys.Rev. B. **87**, 104503 (2013).
[2] A.M. Gabovich, M.S. Li, H. Szymczak, A.I. Voitenko, Phys.Rev. B. **92**, 054512 (2015).

Multiscale analysis of impulse transmission in nonhomogeneous low-dimensional systems

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Familiar FPU problem nevertheles has been studied in many details leave to us a set of nonclear aspects concerned physical properties of dynamic proccesses which happens at intermitency between discrete and continous limits of the equations which governed the wave transport in complex dynamic media. Towards these aspects the intensive study of the transmission of energy impulse througth the low-dimmensional systems of discrete particles which interract with each others by elastic forces shows us the possibility of specific transformation which happens between dispersive and nonlinear modes(like solitons).We show how already in the linear approximation in nonhomogeneous systems the formation of nonlinear modes can be induced with the help of disordering which interplay with other parameters like nonlinearity and dimmension.For low-dimensional (1D) systems which are always topologically ordered we apply Dayson consept of disorder to show the possibility of the formation of localized modes already in linear limit. We found a set of rigorous solutions of governed equations for wave transmition througth 1D Hertzian chains either under the finit lenth or infinite chain length including the case of specific decoration. Obtained resoults shows a complex multiscaled character of the wave transport in 1D nonhomogeneous systems of the force centers which happens at intermitency between discrete and continous limits for governed equations.The possibility of the existence of somewhat like WKB approach for linking the solutions related to the different scales of wave transport in inhomogeneous media has been discussed.

[1] Gerasymov O.I.Vandewalle N.Towards rigorous solutions of the problem of impulse transport in nonhomogeneous Hertzian chain //Ukranian Journal Dopovidi NAN.– 2012. – N8.– P.67.
[2] Lumay G, Dorbolo S, Gerasymov O and Vandewalle N., Experimental study of a vertical column of grains submitted to a series of impulses. //Eur. Phys. J. E – 2013.– Vol.36, N16.

On scaling asymptotic behavior of observables in collisional kinetic theory

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In the talk we consider a new approach to the description of the kinetic evolution of large hard sphere systems within the framework of marginal observables. The links of the hierarchy of evolution equations for marginal observables (the dual BBGKY hierarchy) and the nonlinear kinetic equations for states are established.

The Boltzmann–Grad asymptotic behavior of a nonperturbative solution of the Cauchy problem of the dual BBGKY hierarchy with hard sphere collisions is constructed [1]. The stated asymptotics is governed by the set of recurrence evolution equations, namely, by the dual Boltzmann hierarchy. For initial states specified in terms of a one-particle distribution function we prove that the mean value functional for the constructed limit of additive-type marginal observables is equivalent to the mean value functional determined by a one-particle distribution function governed by the Boltzmann kinetic equation.

One of the advantages of this approach to the derivation of kinetic equations from underlying hard sphere dynamics consists in an opportunity to construct the Boltzmann-like kinetic equation with initial correlations and it gives to describe the propagation of initial correlations in the Boltzmann–Grad scaling limit [2].

Moreover, using suggested approach, we also derive the non-Markovian generalization of the Enskog kinetic equation and construct the marginal functionals of states, describing the creation of all possible correlations of particles with hard sphere collisions in terms of a one-particle distribution function [3]. The Boltzmann–Grad asymptotic behavior of a nonperturbative solution of the stated Enskog equation and the marginal functionals of states are established.

The obtained results we extend on systems of hard spheres with inelastic collisions [4]. In particular, we establish that in a one-dimensional space the kinetic evolution of a system of hard rods with inelastic collisions is governed by the certain generalization of the known Boltzmann equation for a one-dimensional granular gas.

[1] V.I. Gerasimenko, Proc. Inst. Math. NASU. **10**, 71 (2013).
[2] V.I. Gerasimenko, A.G. Kornienko, Reports of NAS of Ukraine. **3**, 17 (2015).
[3] V.I. Gerasimenko, I.V. Gapyak, Kinet. Relat. Models. **5**, 459 (2012).
[4] M.S. Borovchenkova, V.I. Gerasimenko, J. Phys. A: Math. Theor. **47**, 035001 (2014).

Classification of degenerate equilibrium states of magnets with spin s=1

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The problem of classification of equilibrium states with spontaneously broken phase and magnetic symmetries for spin s = 1 systems in the presence of the vector, or scalar and tensor order parameters has been investigated. These order parameters are linear or bilinear with respect to Bose creation and annihilation operators. We considered normal equilibrium states for Bose systems and formulated their magnetic properties of SO (3) or SU (3) symmetry. Classification of degenerate equilibrium states of spin s = 1 magnets condensed matter is carried out on the basis of the quasiaverages conception [1]. For this approach it is very significantly assumption of the residual symmetry of the degenerate state of equilibrium, and the presence of certain transformation properties of the order parameter [2].

Equations of classification of equilibrium states are formulated and their solutions are given in terms of the values of the residual symmetry generator parameters. For a vector order parameter clarified that there are three types of residual symmetry generators. Classification of the scalar and tensor order parameters is considered and conditions the thermodynamic coexistence of these order parameters are clarified. It is shown that a set of six discrete parameters of the generator residual symmetry completely defines all possible structures tensor order parameter. Parameters plots for the generator residual symmetry are constructed.

We have analyzed in details the allowable set of discrete values of the residual symmetry generator parameter that distinguishes the superfluid states of equilibrium. The investigated superfluid states for spin $s = 1$ magnets compared with inert superfluid phases of ^3He, which are characterized by two discrete quantum numbers ($m_s = 0, 1, -1$) and ($m_l = 0, 1, -1$) and two orthonormal frame in spin and configuration spaces. The equilibrium states of the superfluid phases of spin $s = 1$ magnets are characterized by orthonormal rapper in spin space and certain discrete set of values. These values are scalar functions of the invariants which constructed from the parameters of the residual symmetry generator.

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Structure of ^{14}C and ^{14}O Nuclei within a Five-Cluster Model

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Within a five-particle model (three α-particles plus two nucleons), the structure functions of mirror nuclei ^{14}C and ^{14}O are studied. The interaction potentials are proposed to fit the experimental energy and radius of ^{14}C nucleus, as well as the energy of ^{14}O. Using the variational approach with Gaussian bases [1,2], the energies and wave functions are calculated for these five-particle systems. The r.m.s. charge radius of ^{14}O nucleus is found to be 2.415 ± 0.005 fm. The charge density distributions and the form factors of both nuclei are predicted. It is shown that the extra nucleons of both nuclei move mainly inside the ^{12}C three-particle cluster, so that the probability to find the extra nucleons outside this cluster is rather small (being about 0.14 for ^{14}C nucleus and about 0.16 for ^{14}O nucleus).

The pair correlation functions of both nuclei are analyzed, and the r.m.s. relative distances are calculated. Although the corresponding distances in ^{14}O nucleus are found to be greater than those in ^{14}C one due to the additional Coulomb interaction, we show that the r.m.s. charge radius of ^{14}O nucleus is smaller than that for ^{14}C. This "paradoxical" fact is explained by the contribution of extra protons located mainly near the center inside ^{14}O nucleus. The momentum distributions of particles are calculated and analyzed for both nuclei. It is found that the extra nucleons move about 4.4 times faster than the α-particles do, mainly due to the ratio of their masses.

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Conformal field theory and isomonodromic deformations

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It is shown that the tau-functions of isomonodromic deformations of Fuchsian systems of rank N can be given as a Fourier transformation of conformal blocks of W_N-algebras with respect to intermediate dimensions. In the particular case of $N = 2$, this construction gives an explicit solution for tau-function of Painléve VI equation in terms of conformal blocks of Virasoro algebra.

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Magnetic phases in ultracold spinor atoms

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This contribution provides an overview of our recent work [1-5] on the physics of ultracold spinor atoms. I will focus on effective fileld theories describing competing magnetic orders in the regimes of enhanced symmetry (particularly, in the vicinity of the SU(3) ferro- and antiferromagnetic points in the case of spin-1 bosonic atoms, and near the Sp(4)-symmetric line for spin-3/2 fermions).

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Surface energy of semi-infinite jellium

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The development of quantum-statistical theory of Fermi systems with interfaces is one of the most important problems of contemporary statistical physics. In particular, the richness of surface phenomena and the rapid development of experimental methods of investigation of surfaces requires the development of theory of such systems. The most popular theoretical method for studying in the area of research is the density functional theory [1]. By construction, the density functional theory is the one-particle approach and can not properly take into account the many-body correlation effects and as a result the density functional theory has a characteristic problem of surface energy.

By using the method of functional integration, we built the quantum-statistical theory of simple semi-bounded metal within the framework of the semi-infinite jellium [2]. A general expression for the thermodynamic potential of the model of semi-infinite jellium is obtained. By using this expression and the step potential model of surface potential, the surface energy for the infinite barrier model is calculated [3]. The barrier height is found from the condition of the minimum of the surface energy. It is shown that this minimum is caused by the Coulomb interaction between electrons. The surface energy is positive in the entire domain of the Wigner-Seitz radius of metals in contrast to [1], and it is in sufficiently good agreement with experimental data.

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Geometry and entanglement of a two-spin quantum state in evolution

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We study the quantum evolution of two spins with the isotropic Heisenberg interaction in the magnetic field. It is shown that this evolution happens on a two-parametric manifold which is a torus [1]. The entanglement of the states belonging to this manifold is investigated. We obtain that the curves of constant entanglement on the manifold are circles with the radii depending on the parameters of initial states. We generalize this problem in the case of the anisotropic Heisenberg interaction between spins. The dependence of the geometry and entanglement of the states on the ratio between the interaction couplings is investigated. We obtain the time of evolution between the disentangled state and the maximally entangled one. It is shown that the greater the ratio between interaction couplings, the faster the system reaches the maximally entangled state. Finally, a similar problem for two spins described by the Dzyaloshinsky–Moria Hamiltonian is examined. In this case we also obtain that the evolution of two spins happens on a two-parametric manifold with geometry depending on the ratio between the interaction couplings.

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Comparative description of the evolving universe in classical and quantum geometrodynamics

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The description of the universe evolving in time according to general relativity is given in comparison with the quantum description of the same universe in terms of wave functions. For the maximally symmetric geometry, it is shown that the main equation of the quantum geometrodynamics is reduced to the non-linear Hamilton-Jacobi equation. Its non-linearity is caused by a new source of the gravitational field, which has a purely quantum dynamical nature, and is additional to ordinary matter sources. In the semiclassical approximation, the non-linear equation of motion is linearized and reduces to the Friedmann equation with the additional quantum source of gravity (or anti-gravity) in the form of the stiff Zel'dovich matter. The semiclassical wave functions of the universe, in which different types of matter-energies dominate, are obtained. As examples, the cases of the domination of radiation, barotropic fluid, or new quantum matter-energy are discussed. The probability of the transition from the quantum state, where radiation dominates into the state, in which barotropic fluid in the form of dust is dominant, is calculated. This probability has the same order of magnitude as the matter density contrast in the era of matter-radiation equality.

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Impact of cluster polarization on spectrum of ^{10}Be

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We study elastic and inelastic α+^{6}He scattering and spectrum of bound and resonance states in ^{10}Be. This investigation is carried out within a three-cluster microscopic model which was formulated in [1]. In this model nucleus ^{10}Be is represented as a three-cluster system $\alpha + \alpha$+^{2}n. We treat the ^{10}Be as a many-channel system which involves two coupled binary cluster configurations: α+^{6}He and ^{8}Be+^{2}n. ^{6}He= α+^{2}n and ^{8}Be= $\alpha + \alpha$ are considered to be weakly bound two-cluster subsystems, which can change their size on approaching the third cluster (alpha particle or dineutron). We shall use the term "cluster polarization" to mean such change of size of a two-cluster subsystem.

We demonstrated that the cluster polarization has a substantial impact on the energy of bound states and energy and width of resonance states as well. The inclusion of two unpolarized coupled cluster configurations was shown to have approximately the same impact on the spectrum of the ^{10}Be nucleus as allowing for cluster polarization within an isolated cluster configuration.

Aimed at finding how the shape of nucleon-nucleon potential affects spectrum of bound and resonance states, we involved three effective semi-realistic potentials in our calculations. The Majorana parameter of the Volkov and modified Hasegawa-Nagata potentials and the exchange parameter u of the Minesota potential were adjusted to reproduce the 0^+ ground state of ^{10}Be with respect to the $\alpha +^6 He$ threshold. However, the spectrum of bound and resonance states of ^{10}Be was found to be strongly dependent on the shape of nucleon-nucleon forces.

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To the problem of correlation properties of light generated in superradiance processes

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The traditional approach to the investigation of superradiant system behavior [1] consists in eliminating the photon variables from the kinetic equations and studying the evolution of the emitter subsystem. The Bogolyubov method uses the assumption of the equilibrium field state at a certain temperature. Superradiance arising is revealed by the fast changes in the emitter subsystem after some delay time. Such approach does not enable us to find any characteristics of the generated light. We have developed the kinetic theory of the relaxation process in a Dicke system of two-level emitters interacting with electromagnetic field on the basis of the Bogolyubov reduced description method with more detailed picture of the field [2]. Then at least simultaneous binary correlation functions [3] are necessary. Thus, it becomes possible to study the properties of field including the generation of non-classical states (squeezed etc.) [4].

Research into the processes of the non-equilibrium evolution of excited atoms interacting through the field [1] gives some interesting principal results for a concentrated system of emitters and shows the way to the account of the system geometry via using so called diffraction functions. Our picture [2] deals with energy density of the emitter subsystem and averaged values of the field strengths (both E and B) and correlation functions for different points (and pairs of points) at fixed time moments as parameters of the reduced description. Notice that such description remains still macroscopic and modern computer technology (GPU calculations etc.) makes it possible to investigate such a complicated set of differential equations. The Glauber correlation functions [3,4] serving as a tool for diagnostics of the field correlation properties can be expressed via simultaneous correlation functions describing field states in our regular approach.

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Deformed oscillator realization of composite fermions vs composite bosons, and some applications

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Composite bosons (like mesons, excitons, Cooper pairs, atoms) built of two constituent particles were already studied from the viewpoint of their deformed-oscillator operator realization [1], including the entanglement measures aspects [2,3]. An analogous study of composite fermion type particles is initiated [4] herein for two cases: (i) "boson + fermion" composite fermions; (ii) "deformed-boson + fermion" composite fermions. Within the general case of (i) and some subcases of (ii) fermionic realization of the composite fermions is found that implies the obtained admissible wavefunctions $\Phi_\alpha^{\mu\nu}$ from the creation operator $A_\alpha^\dagger = \sum_{\mu\nu} \Phi_\alpha^{\mu\nu} a_\mu^\dagger b_\nu^\dagger$ of the composites.

Like for the composite bosons' realization applied to some entanglement issues [2,3] (and also touched in the context of deformed Bose gas models [5]), for the realized composite fermions such entanglement measures as entanglement entropy and purity are expressed [4] through the parameters involved in matrices $\Phi_\alpha^{\mu\nu}$. The realization of the composite fermions may be applied to such systems as trions or baryons if two constituents form a bound state modeled by deformed boson.

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The Big Bang as a result of the first-order phase transition driven by changing scalar curvature in expanding early Universe

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We consider a possible scenario of evolution of the early Universe born as the result of a fairly large quantum fluctuation of the vacuum and filled with scalar, vector and fermionic fields. The complex amplitude of the non-linear scalar field ϕ with “imaginary mass” μ and ϕ^4 nonlinearity is characterized by the finite vacuum average ϕ_0 in the ground state, while the minimum of the potential energy of the scalar field $U_{\min} \sim \mu^2\phi_0^2$ determines the initial energy density of the vacuum. It is shown that the equation of state of the degenerate relativistic non-ideal Fermi-gas with short-range repulsion between fermions, provided by the massive vector field, may be written as $P = \nu\varepsilon$, where P and ε are the pressure and the energy density of the Fermi-gas, and ν is the dimensionless coefficient which depends on the concentration of fermions n_F and in the broad range of n_F values satisfies conditions $1/3 < \nu < 1$. Due to the interaction between scalar and gravitational fields described by the dimensionless constant ξ and proportional to the scalar curvature of the 4-space $R = \kappa[(3\nu-1)\varepsilon-4\lambda_0]$ (where κ is the Einstein's gravitation constant), the decreasing of ε in the process of expansion of the early Universe leads to the first-order phase transition, driven by the “external field” parameter proportional to the variable scalar curvature. We show that for some minimal permissible value of the constant ξ the radius of the exponentially expanding Universe diverges as the Universe approaches the point of phase transition, with simultaneous divergence of time needed to reach this point, in accordance with the “hyperinflation” scenario, considered earlier [1]. Nevertheless, in the region of metastable states $R < 0$ the first-order phase transition may occur at finite times when $R > R_c$, due to the fragmentation of the “inflating” isotropic and uniform Universe with appearance of spatially heterogeneous domains, which may individually overcome the potential barrier with farther “rolling down” into the deeper minimum of the potential energy. Such a domain serves as the germ of our Universe, while the energy of the scalar field released in its volume leads to the birth of a large number of massive particles and antiparticles. Their subsequent almost total annihilation plays the role of the Big Bang and starts the hot phase in the evolution of our Universe.

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Ground-state properties of dipolar Bose mixtures

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We rigorously discuss properties of two-component Bose mixtures both with dipole-dipole interaction as well as point-like repulsion between particles at zero temperature limit. In particular, using Popov's hydrodynamic formulation we exactly analyzed the structure of low-lying excitations and examined the infrared behavior of one-particle Green's functions. The presence of strong electric field that orients all dipole moments along one direction leads to anisotropic superfluid properties of the system. It is shown that the spectrum of collective modes is characterized by two phonon-like branches with direction-dependent sound velocities. In general, these two velocities can be related to the macroscopic parameters of the system.

Within first-order perturbation theory we approximately calculated superfluid densities, sound velocities and condensate depletion for both components of the mixture.

Electron Transport in Layered Conductors under Lifshits topological transition

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We study theoretically the kinetic characteristics (magnetoresistance, Hall field, thermoelectric field) of layered conductors with a multi-sheeted Fermi surface (FS) under conditions of Lifshits topological transition [I. M. Lifshits, Zh. Eksp. Teor. Fiz., 38, 1569 (1960)], when the topology of the FS may change under the external influence on the conductor, such as pressure or doping impurity atoms. On the example of the Fermi surface consisting of a cylinder and two planes, slightly corrugated along the projection of the momentum along the normal to the layers, we perform analysis of the dependence of the kinetic coefficients on the strong magnetic field **H**, when the cyclotron frequency ω_c of the conduction electrons is much higher than the frequency of their collisions $1/\tau$. In the vicinity of the topological transition, when the distance between the various cavities (sheets) of the Fermi surface becomes small, the electron can be moved from one sheet of FS to another with probability due to magnetic breakdown, and its trajectory in a magnetic field becomes complicated and confused. In this way the quadratic increase with a magnetic field of the resistance to the electric current across the layers in the absence of a magnetic breakdown ($w = 0$) is changed by a linear dependence on **H** when $w \geq \gamma = 1/\omega_c\tau$. At $1 - w \leq \gamma$ the linear growth of the interlayer resistance with **H** reaches saturation. Hall field essentially depends on the probability of magnetic breakdown, but its asymptote in the collisionless limit is independent on τ for all values of w. At $w = 1$ the quasi-planar sheets of the Fermi surface touch the corrugated cylinders, and with the further action of the perturbation on the conductor there is a break of flat sheet along the line of contact. As a result separate sections of a flat sheet of FS together with the cut halves of the corrugated cylinder form finally the new corrugated cylinder, thus the sign of charge carriers is reversed. This is not the only way of Lifshitz topological transition, and the study of the Hall and the Nernst-Ettingshausen effects will provide additional important information about the nature of changes in the topological structure of the electron energy spectrum under the phase transition.

A simple model of Bose-Einstein condensation of interacting particles

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A model of Bose-Einstein condensation of interacting particles is proposed [1]. The account for the interaction between particles eliminates difficulties in the description of condensation available in the model of an ideal gas, which are connected with fulfillment of thermodynamic relations and an infinite value of the particle number fluctuation in the condensate phase. It is shown that in the condensate state the dependence of thermodynamic quantities on the interaction constant does not allow an expansion in powers of the coupling constant. Therefore it is impossible to pass to the Einstein model of condensation in an ideal Bose gas by means of a limiting passage, setting the interaction constant to zero.

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Structure and Dynamics of Domain Walls in Magnetic Helices Under the Action of the Rashba Torque

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A magnetic helix with a constant curvature κ and torsion τ is one of the simplest objects revealing the impact of the geometry onto magnetic properties. Here [1] we analytically and numerically describe the statics and dynamics of a domain wall in magnetic helices with easy–tangential anisotropy using $q - \Phi$ model.

Shaping a uniaxial Heisenberg magnet in a helical wire results in the emergence of an effective anisotropy and effective Dzyaloshinskii–Moriya interaction (DMI), which alter the magnetization state [2, 3]. The effective anisotropies cause the tilt of the equilibrium magnetization with respect to the tangential direction by an angle $\psi \propto \kappa\tau$ and determine its orientation within the tangent–binormal surface. The head–to–head domain wall structure is affected by the effective DMI with the coordinate–dependent deformation proportional to τ. The sign of τ (helix chirality) determines the magnetization direction in the center of the domain wall: inside or outside the helix.

In contrast to rectilinear systems [4], the Rashba torque emergent in the geometry with the parallel electric current injection can efficiently move domain walls. Below the Walker limit the wall velocity is $v \propto \sin\psi/(1 + \tau^2\ell^2)$ with ℓ being a magnetic length. There is an optimal torsion τ when the mobility of a domain wall reaches the maximum absolute value.

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On phase transitions in continuum systems:cell gas model

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A cell gas model of an infinite system of point particles interacting via two-body strong superstable potential is considered. This model is an approximation (to within any preassigned accuracy) of the infinite system of point particles in $\mathbb{R}^d$ in sense that its thermodynamic functions(free energy and pressure) and correlation functions are close to the corresponding quantities of the conventional continuous systems if the mesh size of cells tend to zero. Then we introduce an approximating potential so that the interaction between two particles in different cells are described by the same potential, which depends on the distance between the centers of the cells. These two successive approximations convert a model of permanent gas in the lattice gas model on $a\mathbb{Z}^d$, and thermodynamic functions and correlation functions of these three models will be the same in the limit $a \to 0$. For sufficiently low temperature $T < T_{cr}$ and sufficiently large density $\varrho > \varrho_{cr}$ there exists an interval $[v_1, v_2]$ in the region of definition of the free energy $f^{(a)}(v, T)$ (a^d is the volume of cell) as a function of the volume per particle $v = 1/\rho$, in which it is a linear function of v, and the corresponding function of the pressure $p^{(a)}(v, T) = \partial f^{(a)}(v, T)/\partial v = const$. Such behaviour of the system proves an existence of phase transitions for any $a > 0$. This report is based on the articles[1, 2].

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Emulation of anyons at the bosonic end

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A model of fractional statistics emulating free anyons is considered. According to previously established properties of several types of statistics, one can obtain the virial expansion coinciding with anyonic one up to the third virial coefficient. The the fourth virial coefficient, however, appears to have an opposite sign comparing to free anyons [1,2]. In order to achieve further improvements, the following functional form of the occupation numbers is considered:

$$n_j = \frac{1}{z^{-1}X(\varepsilon_j/T) \pm 1} \qquad \text{with} \qquad X(\xi) = e^{\xi}\Big[1 + \alpha f_1(\xi) + \alpha^2 f_2(\xi)\Big].$$

The bosonic limit corresponds to the anyonic parameter $\alpha \to 0$.

To facilitate the analytical handling of the problem, the coefficient functions can be considered in the following form:

$$f_i(\xi) = e^{-\xi} \sum_{\ell=1}^{\ell_{\max}} k_{i\ell}\xi^{\ell},$$

Comparing the virial expansion in this model to the known results for free anyons [3], one can thus emulate the latter up to α^2 in the anyonic parameter. Depending on $\ell_{\max}$, both the fourth ($\ell_{\max} = 3$) and higher virial coefficients can be recovered.

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Electron-phonon interaction in cascades of nano-devices

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From the time of the first quantum cascade lasers [1, 2] have been fabricated, the scientists are still researching and improving the operating characteristics of these nano-devices. The modern quantum cascade lasers with the wave-lengths of infrared range can operate in the wide interval of temperatures, from cryogenic till the room one. Thus, it is obvious that the electron-phonon interaction, due to the dependence of optical phonons occupation numbers on the temperature, effects on the spectral characteristics of nano-devices, in particular, on the radiating band and needs the detail investigation.

In the proposed paper we develop the theory of electron-phonon interaction in two-well resonant tunneling nano-structure driven by the constant electric field at the finite temperature using the approximation of effective mass for the electron and dielectric continuum model for the optical confined and interface phonons in the framework of the temperature Green's functions method. The established theory is used for the investigation of the influence of electron-phonon interaction on the electron states and radiation band of two-well cascade of injectorless quantum cascade laser operating in terahertz range, observed in ref. [2].

The contributions of electron interacting with all modes of confined and interface optical phonons into the shift and decay three operating electron states of separate cascade of quantum cascade laser are studied as functions of temperature and intensity of electric field. It is shown that the bigger contribution into the shift and decay of ground electron state is performed by the interaction with confined phonons while into the shift of excited states, vice versa, by the interaction with interface phonons.

It is established that the frequency of laser generation of nano-device almost does not depend on temperature and the width of radiation band weakly increases for the higher temperature.

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Dynamics of charged high energy particles in ultrathin and bent crystals.

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At motion of fast charged particles in crystal under small angle to one of its crystallographic axes or planes there appear correlations between consequent collisions of a particle with lattice atoms, that results in a considerable difference from the particle motion in amorphous medium. In crystal the phenomenon of channeling is possible, at which the particles move inside the channels formed by atom strings or crystal planes. In last years in this area some new directions of activity have been outlined, that are connected with the study of passing of particles through ultrathin and bent crystals under small angle to one of the crystal axes.

At passing of fast particles through ultrathin crystals various coherent and interference effects are possible in particle scattering, for description of which the development of special analytical and numerical methods, such as spectral method, three-dimensional WKB-method, etc., is needed. A particular interest represent itself the study of scenario of transition of particles, after entering into a crystal, into the channeling regime.

The motion of high energy particle in a bent crystal near one of its crystallographic axes may be of regular as well as of chaotic (dynamical chaos phenomenon) character relatively bent strings of crystal atoms. Thanks to these motion mechanisms the effects of beam defection, as well as splitting of the beam into several beams, are possible. This opens new possibilities in the management of charged particle beams by means of small-size crystals.

In the proposed talk some results of studies in given directions are presented. A particular attention is paid to the analysis of last CERN experiments towards the discovery of effects predicted theoretically and proposals for new experiments in the indicated areas.

Nonequilibrium response of a charge density wave ordered insulator

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Nonequilibrium response of the charge-density-wave (CDW) ordered phase to the time-dependent electrical field is investigated for the Falicov-Kimball model. The Kadanoff-Baym-Keldysh formalism is employed within the nonequilibrium dynamical mean-field theory. We exactly solve for the dc current and the order parameter of the conduction electrons as the ordered system is driven by large electric field. In particular, the melting of CDW ordering and decay of Bloch oscillations are analyzed. Besides, we present theoretical consideration of a time-resolved photoemission in the CDW insulators. In these pump/probe experiments, a large amplitude pump pulse excites the system into nonequilibrium and then a higher frequency low amplitude probe pulse photoexcites electrons, which are measured at the detector. We describe effects of electron correlations on the photoelectron spectroscopy and show how the gap fills in as the system is excited, even though the order parameter does not go to zero.

Relativistic wave equations of arbitrary spin in quantum mechanics and field theory

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Relativistic wave equations for the particles with nonzero mass and arbitrary spin suggested by Bhabha, Bargmann – Wigner, Rarita – Schwinger (for spin s=3/2) and other authors are under consideration. The comparison with the equations introduced recently by the author of the abstract is given. The three level consideration (relativistic canonical quantum mechanics, canonical Foldy – Wouthuysen type field theory, locally covariant field theory) is presented. The operator link between the relativistic canonical quantum mechanics and locally covariant field theory of arbitrary spin is found. The important partial examples of spin s=3/2 and spin s=2 cases are considered in details.

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Anderson localization of charge carriers as the outcome of the spectrum rearrangement in impure graphene.

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The linear dispersion of charge carriers is, undeniably, a visiting card of graphene and is responsible for most of its unique properties. Since the existence of Dirac quasiparticles has been proved for graphene, one of the most intriguing issues of its physics is the possibility of their localization by whichever imperfection that can appear in the honeycomb lattice.

Early experiments on graphene-based devices, which were engineered like commonplace field effect transistors, revealed that the sample conductivity never drops below a certain minimal value. This fact, indeed, considerably reduced audacious expectations that corresponding devices are capable of serving as next generation electronic switches. The minimal conductivity existence has produced quite a stir, and its origin has been relentlessly debated. The Dirac-like dispersion of charge carriers constituted the core of this discussion. The uniqueness of the electron subsystem in graphene was pushed to its limits so much that former physics of semiconductors were sometimes categorically declared being utterly unsuitable for this material. It has been speculated that massless, according to their Dirac dispersion, charge carriers cannot be localized by any degree of disorder caused by lattice imperfections or impurity centers. The presumed impossibility to localize Dirac excitations were directly linked to the minimal conductivity phenomenon.

We have theoretically demonstrated that even the simplest impurity model (namely, the Lifshitz one) supports the Anderson localization of charge carriers in graphene, and determined those spectral intervals, in which electronic states are localized for a given amount of point impurities. Further experiments fully confirmed results of our study.

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The BBGKY hierarchy and Fokker-Planck equation for many-body dissipative randomly driven systems

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By generalizing Bogolyubov's reduced description method, we suggest a formalism to derive kinetic equations for many-body dissipative systems in external stochastic field [1]. As a starting point, we use a stochastic Liouville equation obtained from Hamilton's equations taking dissipation and stochastic perturbations into account. The Liouville equation is then averaged over realizations of the stochastic field by an extension of the Furutsu-Novikov formula to the case of a non-Gaussian field. As the result, a generalization of the classical Bogolyubov-Born-Green-Kirkwood-Yvon (BBGKY) hierarchy is derived. In order to get a kinetic equation for the single-particle distribution function, we use a regular cut off procedure of the BBGKY hierarchy by assuming weak interaction between the particles and weak intensity of the field. Within this approximation we get the corresponding Fokker-Planck equation for the system in a non-Gaussian stochastic field. Two particular cases are discussed by assuming either Gaussian statistics of external perturbation or homogeneity of the system.

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Phase transition on parametrical visibility graph

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The use of the parametric visibility graph algorithm to map time series to complex networks (graphs) [1] allows to identify and explore new properties of visibility graphs that are not presented in the ordinary visibility graphs. Relative number of clusters in parametric visibility graph demonstrate power law dependency on the proximity to the critical angle of view above and below it, that allows to calculate corresponding critical indices. The relation between indices shows the existence of an analogy between the behavior of the relative number of clusters and the order parameter in the theory of second-order phase transitions [2] and the percolation theory [3,4], Critical indices of the relative number of clusters in finite scaling mode [5], were calculated.They allow to find indices that are the analogue to correlation length index in second-order phase transitions theory. Each type of investigated time series has its own correlation length index. It was shown that the relative number of clusters in artificial time series near critical angle of view is described by scaling law where the role of external field of second order phase transitions theory plays the accuracy of sampling of time series.

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Non-equilibrium Gibbs free energy and phase transition theory

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Construction of the non-equilibrium entropy and non-equilibrium thermodynamic potentials is actual and fundamental problem of statistical physics [1]. They are necessary to formulate the II law of thermodynamics for non-equilibrium processes and for investigation of phase transitions (see, for example, [2]). Here the Leontovich definition of the free energy for non-equilibrium systems [3] is discussed. It is considered a system which is placed in a bath with a temperature T. Its non-equilibrium state is described with the temperature T, volume V, number of particles N and some parameters η_a. Leontovich states that parameters can be obtained in an equilibrium state in the presence of an external field $\hat{U} = \sum_a h_a \hat{\eta}_a$($\hat{\eta}_a$ are microscopic quantities of parameters η_a, h_a is necessary external field). Let the free energy of the equilibrium system in this field be $F(T,V,N,h)$ $(h \equiv \{h_a\})$. Then basic thermodynamics relation for F can be written in the form [2] $dF = -SdT - pdV + \mu dN + \sum_a \eta_a dh_a$. In this case formula $\eta_a = (\partial F/\partial h_a)_{T,V,N}$ gives a relation between variables η_a and h_a. According to Leontovich [3] the non-equilibrium free energy of the system is given by the relation $F_n(T,V,N,\eta) = F(T,V,N,h) - \sum_a \eta_a h_a$ i.e. a Legendre transformation. As an application of the Leontovich definition the non-equilibrium free energy of an isotropic magnetic in the weak non-equilibrium case

$$F_n = F_0 + \frac{3}{2}\frac{T}{\langle m^2\rangle}m^2 + \frac{63}{40}\frac{\langle m^4\rangle T^4}{\langle m^2\rangle^4}m^4 + O(m^6)$$

and the non-equilibrium Gibbs free energy are calculated. In this case parameters η_a are magnetic dipole moment of system m_n $(m^2 \equiv m_n m_n,\ m^4 \equiv (m^2)^2)$. Here quantities $\langle m^2\rangle$, $\langle m^4\rangle$ are equilibrium correlation functions in the absence of an external magnetic field. In fact, the Landau theory of phase transitions of the second kind and critical phenomena [2] is based on similar expressions and the proposed theory let justify some assumption of the Landau theory.

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Phonon-like excitations and modulational instability in the two-state Bose-Hubbard model

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The quantum lattice gas model describing dynamics of Bose-particles in a lattice with regard to their hopping between equilibrium local positions as well as the on-site repulsion (the so-called Bose-Hubbard model) is considered. It is widely used to describe thermodynamics and energy spectrum of ultracold bosonic atoms in optical lattice. The model is also applied in description of other phenomena, such as quantum delocalization of hydrogen atoms (protons) adsorbed on the surface of transition metal, quantum diffusion of light particles or ionic conductivity in the bulk, thermodynamics of the impurity ion intercalation into semiconductors.

In addition to the standard approach, where bosons are confined in the lowest vibrational levels in the potential wells of a lattice, the model can be extended by inclusion of excited vibrational levels with a higher probability of particle hopping between them. A possibility of BE condensation in the excited bands was considered previously for this case.

In our contribution we investigate the simple two-level model [1], which satisfactory simulates the phonon-like dynamics (at low T), taking into account the transitions of Bose-particles between the ground state and the first excited one in potential wells as well as interaction between them. Calculation of an excitation spectrum is performed within the random phase approximation in the hard-core boson limit. It is shown that in a normal (Mott-insulator) phase the spectrum consists of the one exciton-like band, while in the superfluid (SF) phase with BE condensate an additional band appears. Positions, spectral weights and widths of bands strongly depend on chemical potential of bosons and temperature. Conditions of stability of a system with respect to a lowering of symmetry and the particle displacement modulation (together with modulation of the BE condensate order parameter) are discussed. Phase diagrams, illustrating the region of existence of the super-solid (SS) phase besides the usual SF one, are built. Basing on the obtained results, an alternative mechanism of the SS phase appearance in optical lattices with boson atoms is proposed.

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BBGKY'S chain of kinetic equations, non-equilibrium statistical operator method and collective variable method in the statistical theory of non-equilibrium liquids

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Chain of kinetic equations for non-equilibrium single, double and s-particle distribution functions of particles is obtained taking into account nonlinear hydrodynamic fluctuations. Non-equilibrium distribution function of non-linear hydrodynamic fluctuations satisfies a generalized Fokker-Planck equation. The method of non-equilibrium statistical operator by Zubarev is applied. On the basis of collective variable method a scheme of calculation of the structural distribution function of hydrodynamic collective variables and their hydrodynamic velocities (above Gaussian approximation) contained in the generalized Fokker-Planck equation for the non-equilibrium distribution function is proposed. We divide the contributions from short-and long-range interactions between particles, which stems form the fact that short-range interactions (hard sphere model) will be described in the coordinate space, while the long-range interactions in the space of collective variables. Moreover, short-range component will be considered as basis, which corresponds to the BBGKY'S chain of equations for the model of hard spheres.

Spinor description and integral on-shell representation for curvatures of $D = 5$ gauge fields

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Spinor approach to the description of $4d$ gravitational field initiated by R. Penrose [1] can be extended to other gauge fields and contour integral solutions of free massless field equations had been constructed [2] using the features of two-component $SL(2,\mathbb{C})$ spinors and $SU(2,2)$ twistors [3]. Higher-dimensional generalizations of this construction encounter difficulties because of the more complicated algebra of multicomponent spinors and field-theoretical restrictions imposed by the conformal invariance for $D > 4$. So an approach, in which only Lorentz invariance is manifest, looks more preferable. Respective integral on-shell representation for the curvatures of massless free fields in dimensions $D = 3, 4, 6, 10$ was constructed in Ref. [4]. It makes use of the Lorentz vector and spinor harmonics that ensures Lorentz-covariance.

In Ref. [5] we proposed the generalization of such a construction to the $D = 5$ case. To this end we elaborated on the $Spin(1,4)$ spinor description of the curvatures of Yang-Mills, Rarita-Schwinger and gravitational fields. Their irreducible curvature spinors have been characterized, and dynamical equations and Bianchi identities written in terms of the curvature spinors were analyzed. It has been shown that in the absence of sources there remain non-zero only totally symmetric curvature spinors with $2s$ indices that satisfy first-order differential equations. In the free-field limit they were shown to reduce to the equations for the corresponding linearized curvatures and allow straight-forward higher-spin generalization. These equations may be viewed as a $5d$ counterpart of $4d$ first-order equations [6] obeyed by the generalized Weyl curvature spinors for the spin s field [7]. Obtained results are used for constructing integral representation for the Weyl curvature spinors using $D = 5$ Lorentz harmonics that solves Dirac-type equations.

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Integrable nonlinear Schrödinger system on a ribbon of triangular lattice

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In a series of articles [1–4] we have proposed [1] and investigated [2–4] an integrable nonlinear ladder system of nonlinear Schrödinger type whose network of inter-site resonant coupling bonds make its possible to visualize the spatial arrangement of relevant lattice sites as a ribbon of triangular lattice characterized by the two structural elements (sites) in the unit cell. Due to its multi-component structure consisting of two basic mutually symmetric subsystems and one concomitant subsystem the primary integrable nonlinear system exhibits a number of important and even unusual properties. Thus it is capable to incorporate the uniform external magnetic field in terms of Peierls phases as well as to include the effect of uniform external field presumably of electric origin so valuable for rigorous modeling of Bloch oscillations. The most unexpected characteristic of the system as a whole is its criticality against the value of background parameter regulated by the limiting values of concomitant fields. Namely at the critical point the number of basic field variables is reduced by half and the system Poisson structure becomes degenerate. On the other hand outside the critical point the system Poisson structure turns out to be an essentially nonstandard one and the meaningfull procedure of its standardization leads inevitably to the breaking of mutual symmetry between the standardized basic subsystems. There are two possible realizations of such an asymmetric standardization each giving rise to a total suppression of field amplitudes in one of basic subsystems at the critical value of background parameter. In the under-critical region the standardized basic field amplitudes acquire the meaning of probability amplitudes of some nonequivalent intra-cell bright excitations while in the over-critical region such an interpretation is proven to be incorrect. Preliminary analysis shows that the overcritical region could be thought as the region of coexistence between standardized bright and dark excitations. We illustrate the consequences of system criticality on an example of its one-soliton solution. At zero value of background parameter we come to the two symmetrical interacting subsystems of bright excitations each being located on a particular chain of two-leg ladder lattice.

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Systematic investigation of the Hoyle-analogue states in light nuclei

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The Hoyle state is a very narrow 0^+ resonance states in ^{12}C which was predicted by Fred Hoyle in 1954. This resonance state, created by triple collision of three alpha particles, is key element in synthesis of atomic nuclei starting from ^{12}C. In fact, F. Hoyle indicated that synthesis of nuclei in the Universe occurs in nuclear reactions initiated by collision of two nuclei and also by collision of three nuclei. Over the last decade, the Hoyle state and resonance states in ^{12}C embedded in the three-cluster continuum are a subject for the thorough theoretical and experimental investigations (see, for instance, [1] and references therein).

In Ref. [2] we formulated a microscopic model for studying three-cluster continuum. This model is a combination of the Resonating Group Method and Method of the Hyperspherical Harmonics Method. In [1] the model was successfully applied to study bound and resonance states in ^{12}C formed by interaction of three alpha particles. It allowed us to describe correctly energy and width the Hoyle state and other resonance states, and reveal dominant decay channels of these resonance states.

In this report we are going to consider the Hoyle-analogue states in light nuclei ^{9}Be and ^{9}B, ^{10}B, ^{11}B and ^{11}C. In other words, we are going to study whether these nuclei can be created in a triple collision of clusters. Necessary condition for such process is the existence of a very narrow resonance state in three-cluster continuum. Each nucleus is considered as three-cluster configuration consisting of two-alpha particles and s-shell nucleus: neutron, proton, deuteron, triton and ^{3}He. For each nucleus we determine energy and width of resonance states for different values of the total angular momentum J and parity π. We select resonance states with very small width as a candidate to the Hoyle-analogue states. Dominant decay channels are detected for all resonance states under consideration. An analysis of wave function of resonance states shows that the narrow resonance state has a compact three-cluster configuration, while wide resonance state has very dispersed configurations with large distance between interacting clusters. We suggest to use compactness of a resonance state as additional criterion for the Hoyle-analogue state.

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Activity of inhibitory neuron with delayed feedback stimulated with Poisson stream is non-Markov

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Statistics of neuronal activity is often described as a renewal point process, or even a Poisson process. On the other hand, in some sets of experimental data correlations are observed between consecutive interspike intervals, which does not conform with the renewal hypothesis. What could be the reason of such correlations? In principle, any sort of memory in the neuronal firing mechanism could bring about memory into the sequence of ISIs, thus disrupting a possibility for it to be renewal.

Biologically, non-renewal statistics of neuronal activity can improve discrimination of weak signals [1], and therefore is essential feature of functioning of a nervous system.

Normally, any neuron is embedded into a network. Inter-neuronal communication in the network is delayed due to finite speed of nervous impulses. In a reverberating network, this brings about one reason for non-renewal firing statistics - the delayed feedback. In [2], it was proven rigorously that a single *excitatory* neuron with delayed feedback stimulated with Poisson stream has a non-Markov firing statistics. In this work, we extend methods of [2] to *inhibitory* neurons with fast inhibition. In this course we do not specify a concrete neuronal model, only impose a simple set of conditions the model must satisfy. Basic neuronal models, like leaky integrate-and-fire model, or binding neuron model do satisfy those conditions.

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Curvature induced domain wall pinning at a local wire bend

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The interaction of curvature and topologically nontrivial magnetization structures (e.g. domain walls) attracts growing interest in fundamental studies and applications. Domain walls are topologically stable structures which can be used as key elements of nonvolatile magnetic memory devices [1].

Here we study both analytically and numerically the influence of curvature effects on the motion of a domain wall in a planar wire with localized curvature. Our study is based on the phenomenological Landau-Lifshitz equation. To analyze the domain wall properties we use collective variable approach based on $q - \Phi$ model [2].

For a planar wire with localized curvature we show that the domain wall is pinned by the effective potential induced by the curvature. In the case of infinitesimally small wall width ($\Delta_0\kappa(s_0) \ll 1$) the pinning conditions can be written as $\kappa'(s_0) = 0$ and $\kappa(s_0)\kappa''(s_0) < 0$, where $\kappa(s_0)$ is the wire curvature in the minimum of effective potential, Δ_0 is domain wall width, prime denotes the derivative with respect to the arc length. We established that the domain wall motion frequency can be written as:

$$\Omega \approx \omega_0 \pi \ell^2 \sqrt{|\kappa(s_0)\kappa''(s_0)|},$$

where ω_0 being characteristic frequency of the material. The value of frequency of domain wall oscillations within the pinning potential increases with the increasing of curvature [3].

In order to verify our analytical predictions we performed numerical simulations of the Landau-Lifshitz equation using the `NMAG` code [4].

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POSTER TALKS

Anomalous behavior of transport function and density of states for the Falicov-Kimball model with correlated hopping

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We study the thermoelectric properties of the Falicov-Kimball model with correlated hopping on Bethe lattice. We find analytically the electrical and thermal conductivities and thermoelectric power based on the solutions of the dynamical mean field theory. Considering an analytical solution of this model, we analyze an influence of correlated hopping in a wide range of its parameter values. Special attention is payed to the cases where both the density of states and transport function have a sharp or δ-peak at some crossover points. We find that in these particular cases the thermoelectric properties are enhanced in comparison with the common Falicov-Kimball model without correlated hopping.

On the Grad method in the physics of plasma

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We investigate the component distribution functions (CDFs) for a spatially uniform completely ionized two-component electron-ion plasma in the framework of the Grad problem with the help of the generalized Chapman–Enskog method [1]. The reduced description parameters in the framework of the Grad theory are the component particle densities n_a, component velocities v_{an}, component temperatures T_a, component traceless momentum density fluxes π^o_{anl} and component energy density fluxes q^o_{an} taken in the $v_{an} = 0$ reference frame. It is widely used (see, for example, [2,3]) that the component distribution functions are

$$f_{ap} = \frac{n_a}{(2\pi m_a T_a)^{3/2}} e^{-\frac{(p-m_a v_a)^2}{2m_a T_a}} \left[1 + \frac{h_{nlp}\pi^o_{anl}}{2n_a m_a T_a^2} - \frac{2p_n q^o_{an}}{5n_a T_a^2}\left(\frac{5}{2} - \frac{p^2}{2m_a T_a}\right)\right]. \tag{1}$$

where $h_{nlp} \equiv p_n p_l - p^2\delta_{nl}/3$. As seen, (1) is built on the basis of the local equilibrium assumption, but, as known [4], the results of the local equilibrium assumption can be corrected. So the aim of this work is to calculate the CDFs from the Landau kinetic equation and to compare our results with (1). The deviations of the component velocities and temperatures from their equilibrium values and the fluxes π^o_{anl}, q^o_{an} are considered to be small and estimated by a small parameter μ. The theory which is linear in μ is investigated. The perturbation theory in σ ($\sigma = \sqrt{m_e/m_i} \ll 1$) is additionally used. The CDFs in different orders in σ are calculated in the Sonine one-polynomial approximation.

It is obtained that (1) gives the results for CDFs only in the leading order in σ. Corrections to (1) are obtained in higher orders in σ. It is obtained that, in contrast to (1), the electron distribution function depends on the ion momentum and energy fluxes and the ion distribution function depends on the electron ones.

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Acoustic black holes with compact horizons in atomic Bose-Einstein condensates

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It is well known that black holes are the objects from which light cannot escape. Observation of the astrophysical black hole is extremely difficult, so attention has turned to analogue systems in the search for Hawking radiation, event horizon, Penrose mechansim etc[1]. Unlike the ordinary black holes, where speed of light sets Schwarzschild radius, analogous objects in Bose-Einstein condensates (BEC) have speed of sound as a threshold speed. Recently it was experimentally demonstrated [2,3] that flow in some regions of Bose-condensate becomes supersonic, and phonons become disable to escape them.

In present work we suggest a realistic configuration for formation of the acoustic horizon in quasi-twodimentional BEC. Using a mean field model we numerically simulate formation of the two-dimensional and threedimensional 'black holes'. We investigate an analogue of Hawking radiation in these systems.

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Geometrical clusterization in SU(2) gluodynamics and liquid-gas phase transition

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A novel approach to identify the geometrical (anti)clusters formed by the Polyakov loops of the same sign and to study their properties in the lattice SU(2) gluodynamics is developed. The (anti)cluster size distributions are analyzed for the lattice coupling constant β=[2.3115; 3]. The found distributions are similar to the ones existing in 2- and 3-dimensional Ising systems [1]. Using the suggested approach, we explain the phase transition in SU(2) gluodynamics at $\beta = 2.52$ as a transition between two liquids during which one of the liquid droplets (the largest cluster of a certain Polyakov loop sign) experiences a condensation, while another droplet (the next to the largest cluster of opposite Polyakov loop sign) evaporates. The clusters of smaller sizes form two accompanying gases, which behave oppositely to their liquids. The liquid drop formula is used to analyze the distributions of the gas (anti)clusters and to determine their bulk, surface and topological parts of free energy. Surprisingly, even the monomer multiplicities are reproduced with high quality within such an approach. The behavior of surface tension of gaseous (anti)clusters is studied. It is shown that this quantity can serve as an order parameter of the deconfinement phase transition in SU(2) gluodynamics. Moreover, the critical exponent β of surface tension coefficient of gaseous clusters is found in the upper vicinity of critical temperature. Its value coincides with the one found for 3-dimensional Ising model within error bars. The Fisher topological exponent τ of (anti)clusters is found to have the same value 1.806 ± 0.008, which agrees with an exactly solvable model of the nuclear liquid-gas phase transition [2] and disagrees with the Fisher droplet model [3], which may evidence for the fact that the SU(2) gluodynamics and the model [2] are in the same universality class.

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Blockade effect and switching of non-equilibrium depletion forces in gas of interacting Brownian particles

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The concentration-dependent switching of the non-equilibrium depletion interaction between obstacles in a gas flow of interacting Brownian particles is presented. It is shown that this switching is caused by the blockade effect for the gas particles. The nonlinear blockade effect is considerable near the obstacle surface or for closely located obstacles. Screening of the gas flow ahead of the obstacles is accompanied by formation of a compact jammed region ahead of them with a pronounced step-like behavior of the gas density distribution. With gas concentration increasing, the density perturbation around obstacle (obstacle wake) can change its direction to the opposite taking an unusual form with an extended dense region ahead of the obstacle and a depleted localized one behind it. This wake switching leads to the sign change of the effective non-equilibrium interaction between the obstacles, e.g., from effective attraction to repulsion. It is shown that far from the obstacles the asymptotic behaviors of the obstacle wakes and the non-equilibrium depletion forces have multipole character associated with an anisotropic screened Coulomb-like potential with a preferable direction of the anisotropy. In the case of non-adiabatic driving field activation the stationary obstacle wake is a residual perturbation left after the shock-wave (kink) propagation, while the formation of compact dense region ahead of obstacle is a result of shock-wave stopping. The results are obtained within the lattice gas model in the mean-field approximation. The asymptotic behavior is described within the long-wavelength approximation.

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SPECTRA OF COLLECTIVE EXCITATIONS AND GREEN'S FUNCTIONS OF QUADRUPOLE MAGNETIC AND FERRIMAGNETICS.

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The report is devoted to describing of dynamic processes for the set of magnetic states with spin in an external alternating field. We consider ferromagnet and quadrupole magnets with $SU(3)$ symmetry, spin nematic, antiferromagnetic, easy-axis and easy-plane ferrimagnets. Our investigation mainly based on approach of [1,2]. For these magnets closed algebras of Poisson brackets for all magnetic degrees of freedom are obtained. Explicit form of the exchange energy is established in terms of Casimir invariants. Nonlinear dynamic equations for these magnets with sources due to the external field are derived. An effective tool for studying magnetic systems is two-time Green's functions [3,4], the knowledge of which allows us to understand both the state of equilibrium and peculiarities of non-equilibrium processes if the deviation from equilibrium is small. Low-frequency asymptotics of Green's functions for the above magnets are found and their comparative analysis is carried out. The influence of unitary $SO(3)$ or $SU(3)$ symmetry on the structure of Green's functions characteristics are shown and analyzed. Along with the well-known analytical characteristics of Bogolyubov's type some magnetic states have nonBogolyubov's type features.

The pole of the obtained Green's functions determines the spectra of collective excitations of the respective magnetic states. For all considered magnetic states spectra of collective excitations are obtained.

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Generalized diffusion equation in the fractional derivatives in Renyi statistics

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Within the Renyi statistics by the method of the nonequilibrium statistical operator Zubarev the generalized diffusion equation in fractional derivatives was obtained. The Liouville equation in the fractional derivatives was used. Averaging of in the generalized diffusion coefficient is performed by a power distribution with parameter Renyi q.

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Generalization of Chebyshev Polynomials and Knot Invariants

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The Chebyshev polynomials are expressed through Alexander polynomial invariants in terms of q-calculus [1]. From this it follows the idea of obtaining the generalizations of Chebyshev polynomials with the help of the Jones and HOMFLY polynomial invariants for knots and links [2]. Besides, the idea of obtaining of new polynomial invariants for knots and links with the help of generalized Chebyshev polynomials is considered.

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Chemical Freeze-out Irregularities as New Signals of Quark-Gluon Plasma Formation

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Based on the new fit of hadron yield ratios within the multicomponent hadron resonance gas model (HRGM) [1-2] we have found several remarkable irregularities at chemical freeze-out. In particular, 121 hadron multiplicity ratios measured in the nucleus-nucleus collisions at AGS, SPS and RHIC energies were successfully described within the new formulation of HRGM with $\chi^2/dof \simeq 63.978/65 \simeq 0.98$ [2]. A dramatic jump in the center of mass collision energy dependence of $\frac{\Lambda}{p}$, $\frac{K^+}{p}$, $\frac{K^+}{\Lambda}$, $\frac{\Omega^-}{p}$ and $\frac{\Xi^-}{p}$ in the narrow range between 4.3 and 4.9 GeV is found [3]. These irregularities are also accompanied by a sudden increase of the particle decays at chemical freeze-out which is seen at this collision energy range.

We argue that a strong correlation which we observe between the previously found irregularities [1, 3] and an enhancement of strangeness production [4] can serve as the quark-gluon plasma formation signature. Thus, we conclude that a dramatic change in the system properties seen in the narrow collision energy range $\sqrt{s_{NN}} = 4.3 - 4.9$ GeV opens entirely new possibilities for experimental studies of quark-gluon plasma properties at NICA JINR and FAIR GSI accelerators.

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The "quantum" evaluation of absorption coefficient

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In this work the quantum optical theory of absorption/reemission properties of the system of interacting atoms is analyzed. The concept of local absorptance is introduced in the terms of quantum optics, mainly as a derivative of logarithm of intensity with respect to the distance in the vicinity of a given spatial point and a moment of time. The intensity is represented by the averaged normal product of creation and annihilation operators of the certain electromagnetic field states. The averaging is performed over all possible quantum (discrete and continuous) states of the system of the field and atoms. In this case, the statistical weight (or probability density) of every pure state of the total system at an arbitrary moment of time is defined by the state of the system (as a statistical one) at the initial moment of time and the corresponding time interval. The calculation method of the absorption coefficient, as the real part of the definition, is developed taking into account thermal atomic motion, the Doppler effect, and the short-range interaction between atoms. It was shown the formal correspondence between the imaginary part of the definition and the dispersion of the atomic subsystem.

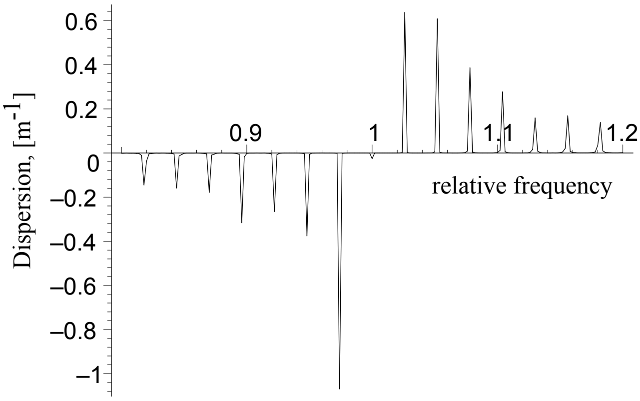

Figure 1 This is the example of the dispersion derived by the theory in the optical region.

Equilibrium magnetization configurations in permalloy spherical shells

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A competition between short-range exchange and long-range magnetostatic interactions in a magnetic nanoparticle results in nontrivial magnetic configuration [1]. Such magnetic distributions as vortex and onion are widely explored for the case of planar structures [2]. In the current study we analyze the phenomena of continuous phase transition between the vortex configuration and onion one for a thin spherical shell [3].

We provide the systematic study of the equilibrium magnetization distributions in the spherical shell. Namely, by combining analytical methods and micromagnetic simulations (MAGPAR code [4]) we determined phase diagram for Permalloy sphere with inner radius R and thickness h: the vortex state is realized for relatively large and thick shells, while the onion state is typical for smaller ones. In contrast to the planar nanoring [5]and hemispherical caps [6] the spherical shell exhibits continuous magnetization transformation from the vortex state to the onion one, which is characterized by the magnetization rotation from the sphere parallel orientation to the meridian direction. The key moment of our study is the simple analytical approach, which gives a possibility to describe different magnetization states as well as the transition between them.

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Mesoscopic Dzyaloshinskii-Moriya interaction

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A broken chiral symmetry in a magnetic system leads to the appearance of both periodical (e.g. helical or cycloid modulations) and localized magnetization structures (e.g. chiral domain walls and skyrmions) [1,2]. *Intrinsic Dzyaloshinskii-Moriya interaction* (DMI) is the origin of all those magnetic textures and arise from the combination of low crystal symmetry and large spin-orbit coupling in magnetic systems [3,4]. Recently, we reported that geometrically broken symmetry in curvilinear magnetic systems also leads to the appearance of *extrinsic exchange driven effective DMI* [5,6]. The extrinsic DMI is linear with respect to curvature and torsion for one-dimensional curvilinear magnetic wires.

Here we study both numerically and analytically the interplay between the intrinsic and extrinsic DMI in one-dimensional ferromagnetic helix wires. The combined intrinsic and extrinsic DMI can be reffered to as a mesoscopic DMI, whose symmetry and strength depend on the geometrical and material parameters. We derive the general expression for the mesoscopic DMI terms and determined the conditions for periodical magnetisation structures to appear in the system. We put forth a simple method to access experimentally the intrinsic DMI constant based on the difference between the average magnetisations for clockwise and counterclockwise helices.

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