

## Monday, December 2

9:30 Welcome

### PLENARY SESSION

Phystech.Bio, 107; Chair: **I.A. Taimanov**

10:00 **A. Hasanoglu** (Kocaeli University, Türkiye)  
Inverse Problems for the Dynamic Euler-Bernoulli Beam

10:35 **S.I. Kabanikhin**, M.A.  
Shishlenin ( ICM&MG SB RAS, Russia)  
Regularization of the Cauchy Problems with Incomplete Data

11:10 **A. Shanenin** (MIPT, Russia)  
Inverse problems in economic measurements

11:45 **A.M. Denisov** (Lomonosov Moscow State University, Russia)  
Existence of solution to inverse coefficient problem for a quasilinear hyperbolic equation with data on characteristics

12:20 **A. Mironov** (Sobolev Institute of Mathematics, Novosibirsk State University, Russia)  
On global solutions of quasilinear systems of equations

12:55 Coffee break & lunch

### Section «Inverse problems and tomography»

Phystech.Bio, 107; Chair: **M.I. Belishev**

14:00 D.V. Lukyanenko, **A. Yagola** (Moscow State University, Russia), Y. Wang (Institute of Geology and Geophysics, Chinese Academy of Sciences, China)  
3D inverse problems of magnetic field restoration from experimental data

14:35 **V.P. Palamodov** (Tel Aviv University, Israel)  
A non-iterative method for electrical property tomography based on explicit formulas

15:10 **L. Pestov** (IKBFU Russia)  
On boundary controllability in the lens rigidity problem

15:45 **A. Jollivet** (CNRS & Université de Lille France)  
Boundary control for transport equations

16:20 Coffee break

16:40 **V.A. Sharafutdinov** (Sobolev Institute of Mathematics, Russia)  
Momentum ray transforms

17:15 **F. Goncharov** (Ecole Polytechnique, France; MIPT, Russia)  
An example of non-unique solvability for a generalized Abel-type integral equation

17:50 I.R. Sabirov (Department of acoustics, Faculty of Physics, M.V.Lomonosov Moscow State University, Russia), **A.S.Shurup** (Department of acoustics, Faculty of Physics, M.V.Lomonosov Moscow State University, P. P. Shirshov Institute of Oceanology, RAS The Schmidt Institute of Physics of the Earth, RAS, Russia)  
Passive ocean tomography based on phase of noise cross-correlation function

18:25 **V. Filatova** (Immanuel Kant Baltic Federal University, Russia))  
Medical ultrasound tomography problem: simulation with attenuation

### Section «Inverse problems in economic measurement»

Main building, 119; Chair: **I.B. Petrov**

14:00 **N. Zyatkov** (Institute of Computational Mathematics and Mathematical Geophysics of SBRAS)  
Machine learning regularization of inverse problem for Black-Scholes equation

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14:35 **N. Trusov** (Moscow State University, Russia)  
Numerical solution of Mean Field Games system with a turnpike effect

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15:10 **Shuhua Zhang** (Tianjin University of Finance and Economics, Chiana)  
Optimal abatement and emission permit trading policies in a dynamic transboundary pollution game

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15:45 **O. Krivorotko** (Institute of Computational Mathematical and Mathematical Geophysics of SB RAS; Novosibirsk State University, Russia)  
Inverse problems and optimization in online social networks

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16:20 Coffee break

**Section «Variational methods»**

Main building, 119; Chair: **I.B.Petrov**

16:40 **V. V. Vedenyapin** (Keldish Inst. Appl. Math., Russia), N. Fimin (Keldysh institute of appl.math, Russia); S. Adjiev (Moscow State University, Russia); I. Melihov (Moscow State University, Russia)  
Boltzmann, Vlasov and Liouville equations.

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17:15 **M. V. Balashov** (IPU RAS)  
Optimization on matrix manifolds

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17:50 **A.V.Arutunov, S.E.Zhukovskiy** (IPU RAS)  
On global inverse and implicit function theorems

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18:25 **S. Lapin** (Washington State University, USA)  
Mathematical Modeling of Applied Problems Arising in Biology and Medicine

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19:00 **N.Khokhlov** (MIPT, Russia); I. Mitskovets (MIPT, Russia); V. Stetsyuk (MIPT, Russia)

Topography modeling in seismic modeling using grid-characteristic method

**Section «Optimization»**

Main building, 123; Chair: **C.A. Uribe**

14:00 **A.V. Gasnikov** (MIPT, Russia)  
Lan's sliding and applications

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14:35 **A. Ryabtsev** (MIPT, Russia)  
The error accumulation in the conjugate gradient method for degenerate problem.

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15:10 **A. Anikin** (ISDCT SB RAS Russia)  
Computational techniques for solving huge-scale problems with sparse solution

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15:45 **M. Alkousa** (MIPT, Russia), D. Dvinskikh (Weierstrass Institute for Applied Analysis and Stochastics, Germany); F. Stonyakin (V.I. Vernadsky Crimean Federal University, Russia); A. Gasnikov (MIPT, Russia); D. Kovalev (King Abdullah University of Science and Technology, Saudi Arabia)  
Accelerated methods for saddle point problems

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16:20 Coffee break

16:40 **V.Matyukhin** (MIPT, Russia); A. Ivanova (MIPT, Russia); E. Kotlyarova (MIPT, Russia)  
Recovery model formation of correspondence matrix

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17:15 **A. Gornov** (ISDCT SB RAS, Russia), T. Zarodnyuk (ISDCT SB RAS, Russia)  
Numerical technologies for optimal control problems

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17:50 **A. Agafonov** (MIPT, Russia), F. Stonyakin (MIPT, Russia)  
Gradient methods for optimization problems that allow for the existence of an inexact strongly convex model of the objective function

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- 18:25 **I. Kuruzov** (MIPT, Russia), F. Stonyakin (MIPT, Russia)  
One Method for Convex Optimization on Square
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- 19:00 **A. Beznosikov** (MIPT, Russia), E. Gorbunov (MIPT, Russia); A. Gasnikov (MIPT, Russia)  
A Derivative Free Method for Distributed Optimization

## Tuesday, December 3

### PLENARY SESSION

Phystech.Bio, 107; Chair: **A.A. Shanani**

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- 10:00 Yu.A. Kordyukov, **I. A. Taimanov** (Sobolev Institute of Mathematics, Russia)  
Quasiclassical approximation for magnetic monopoles
- 
- 10:35 **P. Cerejeiras** (Universidade de Aveiro, Portugal)  
Discrete analogues of the spatial Dirac operator and their function theory
- 
- 11:10 **U. Kähler** (Universidade de Aveiro, Portugal)  
Wavelet and Gabor frames on the three-sphere and inversion of the crystallographic Radon transform
- 
- 11:45 **M. Agranovsky** (Bar-Ilan University and Holon Institute of Technology, Israel)  
Paired shifted Funk transform
- 
- 12:20 **R.G. Novikov** (Ecole Polytechnique, France)  
Formulas for phase recovering from phaseless scattering data

12:55 Coffee break & lunch

### Section « Inverse problems and computations»

Phystech.Bio, 107; Chair: **L. Pestov**

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- 14:00 A.B. Bakushinsky (ISA RAS, Russia), **A.S. Leonov** (National Nuclear Research University 'MEPHI', Russia)  
On numerical solution of a three-dimensional multi-frequency inverse scalar acoustics problem

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- 14:35 **M.A. Shishlenin** (Institute of Computational Mathematics and Mathematical Geophysics Russia)  
Digital twin of acoustic tomography
- 
- 16:40 **M. Elaeva** (HSE, Russia), E. Blanter (HSE, Russia); A. Shapoval (HSE, Russia)  
The inverse problem solution in the Kuramoto model with three non-identical oscillators
- 
- 15:45 **A. S. Fomochkina, B. G. Bukchin** (Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russia)  
Uncertainty of moment tensor determination from surface wave analysis for shallow earthquakes

16:20 Coffee break

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- 16:40 **J. Iglesias Martinez** (RICAM - Austrian Academy of Sciences (Austria)), G. Mercier (Univeristy of Vienna, Austria)  
On the geometrical convergence of total variation regularized linear inverse problems in Banach spaces
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- 17:15 **A. Lapin** (Kazan Federal University, Russia), A. Romanenko (Kazan Federal University, Russia)  
Numerical solving an inverse problem for a subdiffusion equation with fractional order spatial derivatives
- 
- 17:50 **A. Penenko**, (ICM&MG SB; Novosibirsk State University, Russia)  
Inverse problem solution algorithms based on the ensembles of the adjoint equations and quasi-linear sensitivity operator relations

18:25: **Z. Mukatova** (Institute of Computational Mathematics and Mathematical Geophysics; Novosibirsk State University, Russia), A. Penenko (Institute of Computational Mathematics and Mathematical Geophysics, Russia); A. Bobrovskikh (Institute of Cytology and Genetics, Russia); U. Zubairova (Institute of Cytology and Genetics, Russia); A. Doroshkov (Institute of Cytology and Genetics, Russia) Numerical study of the inverse coefficient problem for the base model of the plant cell antioxidant system

**Section «Numerical methods»**

Main building, 119; **Chair: A.V. Lapin**

- 14:00 **E.N. Aristova** (KIAM RAS; MIPT Russia)  
Hermitian characteristic scheme for nonhomogeneous linear transport equation
- 14:35 **A.V. Favorskaya** (MIPT, Russia)  
Assessment of seismic stability using a grid-characteristic method and analysis of wave phenomena
- 15:10 **N.I. Khokhlov** (MIPT, Russia)  
On increasing the accuracy order of the grid-characteristic method for the case of a system with variable coefficients
- 15:45 **A.A. Kozhemyachenko** (MIPT, Russia), I.B.Petrov (MIPT, Russia)  
Calculation of vibrations of railway structures by the grid-characteristic method
- 16:20 **Coffee break**
- Chair: A. Shaninin**
- 16:40 **Ya. Poroshyna** (MIPT, Russia), P. Utkin (ICAD RAS, Russia)  
Mathematical modeling of pulsating detonation wave in the

shock-attached frame using two-stage chemical kinetics model

- 17:15 **V. Golubev** (MIPT, Russia), A. Favorskaya (MIPT, Russia)  
The study of wave phenomena in heterogeneous environments
- 17:50 **V. Aksenov** (MIPT, Russia), A. Vasyukov (MIPT, Russia); K. Beklemysheva (MIPT, Russia)  
Verification of numerical model for thin composite membranes by study of its spectral properties.
- 18:25 **V. Furgailo** (MIPT, Russia), A. Ivanov (MIPT, Russia); N. Khokhlov (MIPT, Russia)  
Research of techniques to improve the performance of explicit numerical methods on the CPU
- 19:00 **P. Stognii** (MIPT, Russia)  
Modelling of seismic waves spread in geological media with hydraulic fracturing by the grid-characteristic method
- 19:35 A. Gordov (MIPT, Russia); N. Khokhlov (MIPT, Russia)  
On the method of applying integral equations in modeling seismic problems

**Section «Optimization»**

Building “Arctica”, lecture hall;

**Chair: A.V.Gasnikov**

- 14:00 **Yu. Nesterov** (CORE UCL Louvain la Neuve )  
Tensor methods with inexactness in auxiliary problem
- 15:00 **Uribe, Cesar A.** MIT (USA), A. Gasnikov (MIPT, Russia); P. Dvurechensky (Weierstrass Institute for Applied Analysis and Stochastics, Germany); D. Dvinskikh (Weierstrass Institute for Applied Analysis and Stochastics, Germany); E. Gorbunov (MIPT, Russia); A. Rogozin (MIPT, Russia)  
Recent Advances in Distributed Optimization over Networks

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15:35 **F. Stonyakin** (V.Vernadsky Crimean Federal University, MIPT, Russia)  
Gradient-type methods for optimization problems with adaptation to inexactness

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16:20 **Coffee break**

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16:40 **A. Rogozin** (MIPT, Russia)  
Accelerated Method for Decentralized Optimization on Slowly Time-Varying Networks

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17:15 **D. Kamzolov** (MIPT, Russia)  
Composite High-order Method for Convex Optimization

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17:50 **N. Tupitsa** (MIPT, Russia), A. Gasnikov (MIPT, Russia); P. Dvurechensky (WIAS, Germany)  
Accelerated Alternating Minimization for Non-convex Problems

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18:25 **P.A. Ostroukhov** (MIPT, Russia)  
Tensor methods for minimizing the objective gradient norm

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19:00 **A. Ivanova** (MIPT, Russia)  
Numerical methods for the resource allocation problem in networks

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## Wednesday, December 4

### PLENARY SESSION

Phystech.Bio, 107; **Chair: A. Mironov**

10:00 M. Belishev, **S.Simonov**, (St. Petersburg Department of V. A. Steklov Institute of Mathematics of the Russian Academy of Sciences, Russia)  
Wave models of some differential operators on the half-line

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10:35 **A.K. Pogrebkov** (Steklov Mathematical Institute and NRU Higher School of Economics, Moscow)  
Singular symmetries of the Hirota difference equation: relation with the Darboux system

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11:10 **M. Pavlov** (Lebedev Physical Institute of RAS, Russia)  
New Class of Two-Dimensional Integrable Linear Equations of Second Order

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11:45 **V.E. Nazaikinskii** (MIPT ; Ishlinsky Institute for Problems in Mechanics RAS, Russia), L. Kuzmina (National Research University Higher School of Economics, Russia); Y. Osipov (Moscow State University of Civil Engineering, Russia)  
On a Deep Bed Filtration Problem with Finite Blocking Time

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12:20 **T. Novikova** (LPICM, CNRS, Ecole polytechnique, Institut Polytechnique de Paris, France)  
Solution of the inverse problem in Mueller polarimetry for the metrology of diffractive optics

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12:55 **Coffee break & lunch**

### Section «Mathematical modeling and PDE's»

Building "Arctica", lecture hall;  
**Chair: E.G. Shifrin**

14:00 **M. Rakhel** (HSE, Russia), V. Danilov (HSE, Russia)  
Construction of fundamental solution to degenerate parabolic equation

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14:35 **D.S. Minenkov** (IPMech RAS Russia), S. Dobrokhotov (IPMech RAS, MIPT, Russia); V. Nazaikinskii (IPMech RAS, MIPT, Russia)  
Asymptotics on 2D nonlinear runoff over slopping bottom

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15:10 **A. Voloshin** (MIPT, Russia), A. Konyukhov (Joint Institute for High Temperatures of the Russian Academy of Sciences, Russia); L. Pankratov (MIPT, Russia)  
Homogenization of chemical reactive flow in double porosity media

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15:45: **A. Astrakhantseva** (Far Eastern Federal University, Russia)  
Optimal control of endovenous laser ablation

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16:20 **Coffee break**

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**Chair: A. Shaninin**

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16:40 **R. Rawat** (Oriental University, India)  
Study of Phylogenetic for computational Evolution of Process, Design and Architectures

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17:15 K. A. Volosov ( Moscow State University of Railway Enginiring, Russia), N. K. Volosova (MSTU named after N.Bauman, Russia), **A.K. Volosova** (LLC Tramplin, Russia), D. Feliksovich (Polotsk S .U. Ph. D.of Math , resp. Belarus)  
The diagnosis of prostate cancer in rats and men

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**Section «Spectral theory and inverse problems»**  
Main building, 119;  
**Chair: V.P. Palamodov**

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14:00 **E. L. Korotyaev** (St.-Petersburg State University, Russia),  
Inverse problem for compactly supported potentials

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14:35 **L. L. Frumin** (IA&E, Novosibirsk (Russia); NSU, Novosibirsk (Russia))  
New Approaches to Coding Information using Inverse Scattering Transform

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15:10 **M.M. Malamud** (Peoples Friendship University of Russia)  
To the spectral theory of infinite quantum graph

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15:45 A.S. Mikhaylov, **V.S. Mikhaylov** (PDMI RAS, Russia)  
Dynamic inverse problem for special system associated with Jacobi matrices and classical moment problems.

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16:20 **Coffee break**

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16:40 **N. Saburova** (Northern (Arctic) Federal University, Russia)  
Invariants for Laplacians on periodic graphs

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**Section « Integrable systems»**  
Phystech.Bio, 107; **Chair: A.K. Pogrebkov**

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14:00 **S. Agapov** (Sobolev Institute of Mathematics, Russia)  
On first integrals of Hamiltonian systems on the 2-torus.

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14:35 **A. Badanin** (Saint Petersburg State University, Russia)  
Third order operator for the good Boussinesq equation on the circle.

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15:10 **P.G. Grinevich** (L.D. Landau Institute for Theoretical Physics, Russia), F. Coppini, P.M. Santini  
The effect of a small loss or gain in the periodic NLS anomalous wave dynamics

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15:45 **V.S. Dryuma** (IMI RM, Moldova))  
On geometric properties of the Navier-Stokes equations

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16:20 **Coffee break**

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16:40 **L.V.Bogdanov** (Landau Institute for Theoretical Physics, Russia)  
Matrix extension of the Manakov-Santini system and integrable chiral model on Einstein-Weyl background

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17:15 **A.S. Demidov** (Moscow State University, Russia)  
Moutard transforms and Cauchy problem for an elliptic equation. Explicit formula of the solution in the case analytical data.

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17:50 **E.G. Shifrin** (MIPT, Russia)  
Aerodynamic Designing the Laval Nozzle for Real Gas

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18:25 **G. B. Sidelnikov**, A. Tarasov ( Huawei, Russia)  
Perspectives of Inverse Scattering Transform in the coherent optical transmission

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**19:00 Conference closing**

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# TALKS

## A. H. Hasanoglu

### Inverse Problems for the Dynamic Euler-Bernoulli Beam

In this talk, a novel mathematical model and new approach is proposed for a class of inverse problems the general form dynamic Euler-Bernoulli beam equation  $\rho(x)u_{tt} + \mu(x)u_{t^2} + (r(x)u_{xx})_{xx} - Tru_{xx} = F(x)G(t)$ ,  $(x, t) \in (0, l) \times (0, T)$  subject to various types of boundary conditions, from available boundary observations (measured output), namely, the measured deflection, slope or moment. The approach is based on a weak solution theory for PDEs, Tikhonov regularization combined with the adjoint method. The Neumann-to-Dirichlet, as well as Neumann-to-Neumann operators of a quasi-solution of the considered inverse problems. Frechet differentiability of the corresponding Tikhonov functionals are also proved. Explicit formulas for the Frechet gradients are derived by making use of the unique solutions of the corresponding adjoint problems. Furthermore, classes of admissible inputs in which the Frechet gradient of the Tikhonov functional is Lipschitz continuous, are derived. Numerical examples with random noisy measured outputs are presented to illustrate the validity and effectiveness of the proposed approach.

## S. I. Kabanikhin

### Regularization of the Cauchy Problems with Incomplete Data

We continue to study the problem of modeling of substitution of production

factors motivated by the need for computable mathematical models of economics that could be used as a basis in applied developments. This problem has been studied for several decades, and several connections to complex analysis and geometry have been established. We describe several models of resources distribution and discuss the inverse problems for the generalized Radon transform arising in these models. We give a simple explicit range characterization for a Radon transform and we apply it to show that the most popular production functions are compatible with these models. Besides, we give a necessary condition and a sufficient condition for solvability of the model identification problem in the form of appropriate moment problem. These conditions are formulated in terms of rhombic tilings.

## A. Shanin

### Inverse problems in economic measurements

We continue to study the problem of modeling of substitution of production factors motivated by the need for computable mathematical models of economics that could be used as a basis in applied developments. This problem has been studied for several decades, and several connections to complex analysis and geometry have been established. We describe several models of resources distribution and discuss the inverse problems for the generalized Radon transform arising in these models. We give a simple explicit range characterization for a Radon transform and we apply it to show that the most popular production functions are compatible with these models. Besides, we give a necessary condition and a sufficient

cient condition for solvability of the model identification problem in the form of appropriate moment problem. These conditions are formulated in terms of rhombic tilings.

*Agaltsov A. D., Molchanov E. G., Shananin A. A. Inverse problems in models of resource distribution // Journal of Geometric Analysis, 2018, v.28, №1, p.726-765.*

## **A. Denisov**

### **Existence of solution to inverse coefficient problem for a quasilinear hyperbolic equation with data on characteristics**

Problem for a quasilinear hyperbolic equation with data on characteristics is considered. Depending on solution coefficient of equation is unknown. Local theorem of existence for problem of determining unknown coefficient is proved.

## **A. Mironov**

### **On global solutions of quasilinear systems of equations**

In this talk we discuss a problem of existence of smooth periodic solutions of quasilinear systems of equations describing integrable geodesic and magnetic geodesic flows on the 2-torus.

The talk is based on joint papers with Misha Bialy, Tel Aviv University.

## **A. G. Yagola, Y. Wang, D. Lukyanenko**

### **3D inverse problems of magnetic field restoration from experimental data**

In this talk we will explain how to solve numerically inverse problems of magnetic field restoration in geophysical applications using supercomputers. We will demonstrate results of experimental data processing.

This work was supported by the RFBR-NSFC grant 19-51-53005

## **V. P. Palamodov**

### **A non-iterative method for electrical property tomography based on explicit formulas**

A non-iterative method of reconstruction of contrast source inversion is proposed from data of MRI system and of a harmonic electro-magnetic field at Larmor frequency. Contrast source includes conductivity and permittivity maps of the object. The exact analytic formula for contrast source function and a geometric method for acquisition of the inductive field will be discussed.

## **L. Pestov**

### **On boundary controllability in the lens rigidity problem**

The talk is devoted to the lens rigidity of riemannian manifolds. An approach based on the ideas of the boundary control is discussed.



## A. Jollivet

### Boundary control for transport equations

We consider 2 types of control for the linear stationary Boltzmann equation in a bounded and smooth domain  $X$  : First control of a transport solution on a subdomain of  $X$  from the incoming boundary condition, and then control of the outgoing solution from incoming condition. In the first case we prove exact control under appropriate convexity assumption of the domain. In the second case we show that control is not feasible for well chosen optical parameters (absorption and scattering) of the domain  $X$ .

This a joint work with G. Bal (Chicago University).

## V. Sharafutdinov

### Momentum ray transforms

The momentum ray transform  $I^k$  integrates a rank  $m$  symmetric tensor field  $f$  over lines of  $\mathbb{R}^n$  with the weight  $t^k$  :

$$(I^k f)(x, \xi) = \int_{-\infty}^{\infty} t^k \int_{\mathbb{R}^m} f(x+t\xi, \xi^m) \mathbf{r} dt. \text{ We}$$

give the range characterization for the operator  $f \mapsto (I^0 f, I^1 f, \dots, I^m f)$  on the Schwartz space of rank  $m$  smooth fast decaying tensor fields. In dimensions  $n \geq 3$ , the range is characterized by some differential equations of order  $2(m+1)$  which generalize the classic John equations. In the two-dimensional case, the range is characterized by some integral conditions that generalize the classic Gelfand -- Helgason -- Ludwig conditions.

This is the joint work with Venky Krishnan, Ramesh Manna, and Suman Kumar (TIFR Centre for Applicable Mathematics, Bangalore, India).

## F. Goncharov

### An example of non-unique solvability for a generalized Abel-type integral equation

Generalized Abel-type equations are known for being one of the important tools in mathematical physics and, in particular, in the domain of inverse problems. From the mathematical side theory of fractional calculus provides many positive theorems on solvability, uniqueness and even stability of solutions for this type of equations. In this talk we show how the recent result of Goncharov, Novikov, 2019, on the non-injectivity for weighted Radon transforms gives counterexamples to the aforementioned theorems when their assumptions are slightly relaxed.

*F. O. Goncharov, R.G. Novikov, A breakdown of injectivity for weighted ray transforms in multidimensions, Arkiv for Matematik, 57(2):333-371, 2019.*

## A. Shurup, I. Sabirov

### Passive ocean tomography based on phase of noise cross-correlation function

Some experimental results are presented, which shows the possibility of estimating a phase of Green's function from a cross-correlation function of noise signals recorded in spatially separated points in shallow sea. The peculiarities of a phase of Green's function near critical frequencies of hydroacoustic modes are discussed. A

scheme for reconstructing the ocean parameters by using information about a phase of the cross-correlation function of the noise field and critical frequencies of hydroacoustic modes is considered; some results of numerical modeling are presented and discussed.

## **V. Filatova**

### **Medical ultrasound tomography problem: simulation with attenuation**

The paper is devoted to the numerical study of the acoustical medium visualization in a formulation close to medical ultrasound tomography. Numerical experiments of visualization of the speed of sound and attenuation using Energy Reverse time migration (Energy RTM) were realized. The final image contains both the image of the speed of sound and the image of the attenuation. These two images are not separated.

This work is supported by the Russian Science Foundation under grant 16-11-10027.

## **N. Zyatkov, O. Krivorotko, S. Kabanikhin**

### **Machine learning regularization of inverse problem for Black-Scholes equation**

The solution of the Black-Scholes equation provides an estimate of the theoretical price of the option which is a derivative of some underlying asset (for example, stocks). The Black-Scholes model is a multi-parameter equation depending on the current price of the underlying asset, the strike price of the option, the time to

maturity of the option expressed in years, the risk free rate as well as the price volatility of the underlying asset expressed in years. Volatility is an important value of the underlying asset risk measure used by portfolio managers. However, it is not possible to clearly observe the volatility of the underlying asset of the option in the financial markets. In practice, market participants work with the so-called implied volatility which is calculated based on the current value of the option observed on the market assuming that this value reflects the expected risks. From the other side, the additional information about option price at fixed times could be obtained. The inverse problem for Black-Scholes equation consists in identification of implied volatility using measured data of option price at fixed times. The inverse problem is reduced to the minimization least square problem that is solved by neural networks with gradient optimization approach. The comparison analysis with other optimization methods is presented and discussed as well as the short term prediction of option price behavior.

The work is supported by the Russian Science Foundation (project № 18-71-10044).

## **N. Trusov**

### **Numerical solution of Mean Field Games system with a turnpike effect**

We consider a problem described by Mean Field Games (MFG) and Optimal Control theory on finite time horizon. This problem consists of a system of PDEs: a Kolmogorov-Fokker-Planck equation, evolving forward in time and a Hamilton-Jacobi-Bellman equation, evolving backwards in time. The difficulties related

to the numerical solution come from a turnpike effect. We present a regularization method of this system of PDEs in a form of the extremal problem and introduce its numerical solution at the heart of monotonic schemes. According to special assumptions, PDEs can be reduced to Riccati ODEs. We consider this reduction as a test example for the numerical solution of the extremal problem.

The work has been supported by RFBR (grant 17-07-00507).

## **S. Zhang**

### **Optimal abatement and emission permit trading policies in a dynamic transboundary pollution game**

We obtain optimal emission levels and abatement expenditures in a finite-horizon transboundary pollution game with emission trading between two regions. We show that emission trading has a big impact on the optimal strategies and profits of the two regions. We find that cooperation between the regions leads to increased abatement and lower emissions, resulting in a lower pollution stock. We also provide a stochastic extension in which the pollution stock and the emission trading price are diffusion processes and solve it numerically.

## **O. Krivorotko, S. Kabanikhin, T. Zvonareva, V. Kashtanova**

### **Inverse problems and optimization in online social networks**

The specifics of the information diffusion in social networks depend on the region, information type and network features. Mathematical models of social processes are described by systems of partial differential equations the coefficients of which characterize the popularity of information, rate of its propagation, initial interests of influenced users. To control information in social networks it is necessary to refine the unique model coefficients and initial data by some additional information about density of influenced users in fixed times (the inverse problem). The inverse problem is reduced to a problem of multi-parametric minimization of the misfit function with a lot of solutions. The aim of the work is to construct an optimization algorithm for solving the minimization problem based on the combination of stochastic, tensor train (TT) optimization and deterministic approaches. At the first step, artificial neural networks determine the approximation of density of influenced users using data from Facebook, Digg.com. Then the stochastic algorithm (particle swarm optimization) and TT optimization determine the global minima domain of the misfit function. The domain of applicable of such algorithms depends of the volume of set of unknown parameters. And at the last step, the discrete multilevel gradient approach as well as Nelder-Mead methods are applied as deterministic ones for better identify of the inverse problem solution. To control the accuracy of inverse problem solution the convergence estimates for the gradient method as well as confidence intervals of approximate solutions are applied and

investigated. The comparison of applied algorithms and numerical results will be presented and described.

The work is supported by the Russian Foundation for Basic Research (project № 18-31-20019) and by the grant of President of Russian Federation (Agreement No. 075-15-2019-1078 (MK-814.2019.1)).

## **V. V. Vedenyapin, N. Fimin, S. Adzhiev, I. Melihov**

### **Boltzmann, Vlasov and Liouville equations**

The hydrodynamic substitution, which is wellknown in the theory of the Vlasov equation [1–3], has recently been applied to the Liouville equation and Hamiltonian mechanics [4–8]. In [4–6], Kozlov outlined the simplest derivation of the Hamilton–Jacobi(HJ) equation, and the hydrodynamic substitution simply related this derivation to the Liouville equation[7, 8]. The hydrodynamic substitution also solves the interesting geometric problem of how a surface of any dimension subject to an arbitrary system of nonlinearordinary differential equations moves in Euler coordinates (in Lagrangian coordinates, the answer is obvious). This has created prerequisites for generalizing the HJ method to the non-Hamiltonian situation. The H-theorem is proved for generalized equations of chemical kinetics, and important physical examples of such generalizations are considered: a discrete model of the quantum kinetic equations (the Uehling–Uhlenbeck equations) and a quantum Markov process (a quantum random walk). The time means are shown to coincide with the Boltzmann extremes for these equations and for the Liouville equation[9]. This give possibility to prove

existence of analogues of action-angles variables in nonhamiltonian situation. Applications to problem of chemical kinetic [10] and to forming of elements [11] in the Universe are proposed.

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6. V. V. Kozlov, *General Vortex Theory (Udmurt. Gos. Univ., Izhevsk, 1998) [in Russian]*.

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## **M. V. Balashov**

### **Optimization on matrix manifolds**

We prove that the real Stiefel and Grassmann manifolds are proximally smooth with certain absolute constants. This permits to prove a linear convergence of the gradient projection algorithm for minimization of a smooth function on these manifolds in some cases.

## **A.V. Arutyunov, S.E. Zhukovskiy**

### **On global inverse and implicit function theorems**

The talk is devoted to conditions for existence of global inverse and implicit functions. In the talk, we present global inverse function theorem, which provides condition for existence of smooth right inverse function to a given smooth mapping acting between Hilbert spaces and gives the inverse function estimates. For an abstract equation defined by a mapping acting between Hilbert spaces with a parameter, we present sufficient condition for existence of a solution for every value of the parameter, for continuity of the solution and solution estimates. In addition, we discuss the question on implicit functions continuous extensions existence.

## **S. Lapin**

### **Mathematical Modeling of Applied Problems Arising in Biology and Medicine**

In this talk we will look at several problems with applications in epidemiology and medicine. Specifically,

we will discuss mathematical modeling of H1N1 influenza epidemic in a small closed community, modeling of biological fluids flow in the human eye and its effect on Glaucoma development and recent advances in developing a model to interpret ballistocardiogram measurements.

## **N. I. Khokhlov, I. Mitskovets, V. Stetsyuk**

### **Topography modeling in seismic modeling using grid-characteristic method**

Finding the way to solve the problem of precise surface description without major performance reduction is a key to improve the accuracy of topographic models. Describing surfaces using traditional spectral-element methods requires complicated mathematical operations to be done on each modeling step, increasing requirements to the hardware resources and reducing the modeling speed drastically in case of lack thereof. Ignoring the surface completely limits a researcher to a quite small class of problems, because the impact of topography makes surface unaware modeling results obviously wrong in most cases. The diversity of existing packages and approaches is quite impressive but at the moment the problem remains unsolved.

This work covers the aspects of applying the grid characteristics method to the problem of both topography and inhomogeneities for two-dimensional problem statements. The correctness of the presented approach is proven by multiple validation tests, comparisons with well-known packages utilizing both quasi-analytical and numerical methods and example modeling results. Furthermore, it

is shown, that the proposed method is capable of increasing performance compared to the pure curvilinear cells based methods without introducing significant errors. Results, presented in this paper are demonstrated to be consistent with previous research results.

This work was supported by the Russian Foundation for Basic Research, project no. 18-31-20041 mol\_a\_ved.

## **A. Gasnikov**

### **Lan's sliding and applications**

In this talk we describe different application of Lan's sliding technique to different convex optimization problems and convex-concave saddle-point problems.

## **A. Ryabtsev**

### **The error accumulation in the conjugate gradient method for degenerate problem.**

In this talk I provide results of a series of experiments with CGD method on noisy task.

## **A. Anikin**

### **Computational techniques for solving huge-scale problems with sparse solution**

The report is devoted to numerical methods for solving problems of large dimension with sparse solution. The problems of web-pages ranking (PageRank) and restoration of the correspondence matrix for large computer networks are considered. The results of computational experiments for problems with dimensions up to  $10^8$  variables are presented.

## **M. Alkousa, D. Dvinskikh, F. Stonyakin, A. Gasnikov, D. Kovalev**

### **Accelerated Methods for Saddle Point Problems**

Recently, many researchers actively working in the subject of accelerated methods for saddle point problems, based on their structure. In our report, we show that the best known bounds for bilinear convex-concave smooth composite saddle point problems [1] keep true for non-bilinear convex-concave smooth composite saddle point problem [2]. As a special case, we consider some examples of an approach studied for saddle point problems, in the case of a lower-dimensional problem [3]. We consider the classical optimization problem of minimizing a strongly convex, non-smooth, Lipschitz-continuous function with one Lipschitz continuous constraint. In the case of several convex non-smooth constraints, we consider one max-type constraint which is also convex. For solving the considered optimization problem, we propose two methods with adaptive stopping rules. In proposed Algorithms, strong convexity of the functional of constraints is not required, and there is also no need to know the value of the strong convexity parameter of the objective function, which is not available in optimal methods, such as Mirror Descent, wherein these methods require the strong convexity and knowing the value of the strong convexity of both objective and functional of constraints. The main idea of the proposed methods is using the dichotomy method and solving an auxiliary one-dimensional problem at each iteration. Theoretical estimates for the proposed methods are obtained. Partially, for smooth functions, we prove the nearly

linear rate of convergence of the methods. We also consider theoretical estimates in the case of non-smooth functions. The results for some examples of numerical experiments illustrating the advantages of the proposed methods and the comparison with some adaptive optimal method (Mirror Descent) for non-smooth strongly convex functions are also given.

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[2] *Mohammad Alkousa, Darina Dvinskikh, Fedor Stonyakin, Alexander Gasnikov. Accelerated Methods for Saddle Point Problems. (2019) <https://arxiv.org/ftp/arxiv/papers/1906/1906.03620.pdf>*

[3] *Fedor S. Stonyakin, Mohammad S. Alkousa, Alexander A. Titov and Victoria V. Piskunova.: On Some Methods for Strongly Convex Optimization Problems with One Functional Constraint. In book: Mathematical Optimization Theory and Operations Research, 18th International Conference, MOTOR 2019, Ekaterinburg, Russia, July 8-12, 2019, Proceedings Springer Nature Switzerland AG 2019. M. Khachay et al. (Eds.): MOTOR 2019, LNCS 11548, pp. 82–96, 2019.*

## **V. Matyukhin, A. Ivanova, E. Kotlyarova**

### **Recovery model formation of correspondence matrix**

In this talk we consider and compare two approaches to recovering the correspondence matrix: gravitational (entropy) and statistical. The smallest standard deviation gives an account of both the distance and the average travel time between the sources and sinks of correspondence. However, if we consider

only the average travel time as costs, the best result (when considering the standard deviation) is given by an approach in which the tail (high costs) of the gravitational function decrease according to a power law, while the dependence on costs for their small value is exponential character.

## **A. Gornov, T. Zarodnyuk**

### **Numerical technologies for optimal control problems**

Numerical technologies are proposed for solving nonconvex optimal control problems, oriented to the search for the global extremum of a nonlinear objective functional. The developed methods are based on a multi-start technique with original combinations of gradient methods, stochastic coverings of the reachable sets of controlled systems, curvilinear search algorithms that use the controls generation as relay, spline and piecewise linear functions. A series of tests and applications are presented.

## **A. Agafonov, F. Stonyakin**

### **Gradient methods for optimization problems that allow for the existence of an inexact strongly convex model of the objective function**

In this talk, some analogs of the Devolder–Glineu–Nesterov ( $\delta_{\cdot}$ )- oracle are introduced for optimization problems. At the same time, various types of conditions of relative smoothness and relative strong convexity of the objective function are highlighted. The adaptive and nonadaptive gradient methods for optimization problems that allow for the inexact model

are studied. The linear rate of convergence of these methods is justified and it is shown that there is no error accumulation on iterations.

## **I. Kuruzov, F. Stonyakin**

### **One Method for Convex Optimization on Square**

We consider some new approach to method convex 2-dimensional optimization on a fixed square recently proposed by Yu. E. Nesterov (see ex.1.5 in <https://arxiv.org/pdf/1711.00394.pdf>). The method can be interested for to solve a dual problem for a convex problem with two functional constraints. The idea of the method consists in the narrowing of the domain until we achieve an acceptable quality of the solution. This method has to search minimum on the separating segments and we propose some non-depended on required accuracy stop condition for it. Estimations for the iterations number are proved for the cases of smooth and non-smooth functions. Besides there is an experimental comparison of our method with other inexact methods of convex optimization such as ellipsoid method with  $\epsilon$ -subgradient and primal and fast gradient method with  $(\delta, L)$ -oracle. The experiments were made on dual problems for problems with two constraints As a result, our method with provided in this work strategy has the best result.

## **A. Beznosikov, E. Gorbunov, A. Gasnikov**

### **A Derivative Free Method for Distributed Optimization**

In this talk, we consider a composite optimization problem. We solve it by the Lan's sliding method with a stochastic gradient.

## **I. Taimanov**

### **Quasiclassical approximation for magnetic monopoles**

We discuss the quasiclassical approximation of magnetic Laplacians corresponding to the case of magnetic monopoles, i.e. non-exact magnetic fields. This is a joint work with Yu.A. Kordyukov.

## **P. Cerejeiras**

### **Discrete analogues of the spatial Dirac operator and their function theory**

During the last decades one can observe an increasing interest in discrete structures due to a fast growing computational power. This evolution in computational power also allows to replace the traditional approach of discretisation of partial differential equations via a variational formulation by a finite element modelation directly on the mesh. This also opens the way for discrete analogues to the usual continuous structures, in particular a discrete function theory. While there is a deep and long standing theory in the two-dimensional case, which has applications to problems in probability and statistical physics (see D. Chelkak, R. Novikov, S. Smirnov, just to name a few) the higher dimensional case is



only recently being developed. Hereby the pioneered approach by V. S. Ryabenskij, K. Gürlebeck and W. Sprößig in the end of the eighties, based on potential theory, had a relative success. It also had a drawback of having no overall operator theory, namely, no discrete equivalent notions to elliptic operators, strongly singular operators, and so on. In this talk we will present a discrete operator theory based on a combination of finite differences calculus and complexified Clifford algebras which leads to the necessary tools, like discrete Cauchy kernels, discrete Hilbert- and Riesz-transforms, and Hardy spaces. Special emphases will be given to the study and application of discrete Riemann-Hilbert boundary value problems.

## U. Kaehler

### Wavelet and Gabor frames on the three-sphere and inversion of the crystallographic Radon transform

There is a wide range of applications for function systems on  $S^3$ , among them X-Ray diffraction tomography whose mathematical model is given by the spherical X-ray transform. Here, one needs to reconstruct the so-called orientation density function which is a well-localized function on  $S^3$ . To approximate such a function we discuss the construction of Wavelet and Gabor frames on the three-sphere. In both cases we use the representation of the corresponding group (Lorentz group in the case of the wavelet transform and Euclidean group in the case of the Gabor transform). While this provides us with the continuous transforms in reality we need a discrete version. To this end we will use co-orbit space theory to construct wavelet and Gabor frames.

Here we will show the difference in the construction of both cases. To illustrate the applicability of our frames we present an algorithm for the inversion of the spherical X-Ray transform.

## M. Agranovsky

### Paired shifted Funk transform

The (shifted) Funk transform  $F_a$  with the center  $a$  integrates continuous functions on the unit sphere  $S^{n-1}$  in  $\mathbb{R}^n$  over the cross-sections by  $k$ -planes containing the point  $a$ . When  $a$  is not in  $S^{n-1}$  then the transform is not injective. We describe all pairs the Funk transforms  $F_a, F_b$  such that any  $f \in C(S^{n-1})$  can be uniquely reconstructed from the pair  $F_a f, F_b f$  of the Funk data and give a reconstruction procedure.

This is a joint work with Boris Rubin.

## R. Novikov

### Formulas for phase recovering from phaseless scattering data

We present formulas for phase recovering from appropriate monochromatic phaseless scattering data.

In particular, these formulas reduce phaseless inverse scattering to standard inverse scattering with phase information.

This talk is based, in particular, on works [1-3].

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## **A. S. Leonov, A. Bakushinsky**

### **On numerical solution of a three-dimensional multi-frequency inverse scalar acoustics problem**

A new algorithm is proposed for solving a three-dimensional scalar inverse problem of acoustic sounding of an inhomogeneous medium from measurements of the complex amplitude of the wave field outside the inhomogeneity region. For data recording “in a thin flat layer”, the inverse problem is reduced using the Fourier transform to solving a set of onedimensional Fredholm integral equations of the first kind, to the subsequent calculation of the complex amplitude of the wave field in the inhomogeneity region and then to finding the desired field of sound velocities in this region. The algorithm allows us to solve the inverse problem on a typical personal computer for sufficiently small three-dimensional grids in a few minutes without parallelization. A numerical study of the accuracy of the proposed algorithm for solving model inverse problems at one frequency and simultaneously at several frequencies is carried out. The stability issues of the algorithm with respect to data perturbations are also investigated.

## **M. Shishlenin**

### **Digital twin of acoustic tomography**

In the talk we investigate and develop numerical methods for identifying models of wave processes. We will study the problem of determining the boundary conditions and coefficients of the systems of acoustics equations, written in the form of conservation laws, according to additional information about the solution of the corresponding direct problems defined on the boundary (or its part) of the area. Such problems arise in medical tomography, flaw detection and non-destructive testing.

## **M. Elaeva, E. Blanter, A. Shapoval**

### **The inverse problem solution in the Kuramoto model with three non-identical oscillators**

We consider the Kuramoto model with three non-identical oscillators. We assume that there is no direct coupling between the top and the bottom oscillators and they are connected only through the middle one. We assume a zero natural frequency of the middle oscillator, and a symmetrical coupling coefficients. We solve the inverse problem and reconstruct natural frequencies of the top and bottom oscillators from their synchronized phases. We describe how the phase difference determines the coupling domain where the reconstruction is unique, correct and stable. And then we apply the Kuramoto model with three oscillators to uncover the relationship between the deep and the near-surface speed of the solar meridional flow.

## **A. Fomochkina, B. Bukchin**

### **Uncertainty of moment tensor determination from surface wave analysis for shallow earthquakes**

We consider the problem of the nonuniqueness of the moment tensor inversion for shallow earthquakes from long period surface wave data. We give an existence condition for double couples radiating the same long period surface waves as the deviatoric moment tensor obtained by such inversion. We describe the family of such double couples and show that they may provide better estimates of double couple mechanisms than the traditional “best double couple” solution.

## **J. A. Iglesias Martinez, G. Mercier**

### **On the geometrical convergence of total variation regularized linear inverse problems in Banach spaces**

We investigate the convergence, as both the regularization parameter and the noise go to zero at a controlled speed, of total variation regularized linear inverse problems in  $\mathbb{R}^n$  with operator which is bounded in  $L^p$ . More precisely, we show the convergence with respect to the Hausdorff distance of level-sets of the regularized solution to the level-sets of the true data when  $p$  and the dimension are linked to each other. We will also discuss simple counterexamples and investigate the source condition assumption under which our theorem holds. In particular, we will see that for denoising in the plane, this condition is not sharp.

## **A. Lapin, A. Romanenko**

### **Numerical solving an inverse problem for a subdiffusion equation with fractional order spatial derivatives**

We numerically solve the problem of identifying the parameters of fractional diffusion. The main feature of the proposed method is the use of explicit approximations with variable time steps for the equation with fractional spatial derivatives. It is known that approximations of such equations lead to systems of algebraic equations with filled matrices, which complicates the use of implicit schemes. As usual, explicit approximations are stable only under rather strict restrictions on the grid parameters. The use of explicit approximations with variable time steps allows one to choose a significantly larger "average" time step than in an explicit constant-step scheme while maintaining the simplicity of the numerical implementation. Several numerical examples are given for solving the problem of identifying the index of a fractional derivative.

## **A. Penenko**

### **Inverse problem solution algorithms based on the ensembles of the adjoint equations and quasi-linear sensitivity operator relations**

The inverse problems for non-stationary advection-diffusion-reaction processes models are considered. The ensemble of solutions to the corresponding adjoint equations can be aggregated to a sensitivity operator that links the variation of the observed values with the variation of the model parameters. With the sensitivity

operator, the inverse problem is reduced to a family of quasi-linear operator equations. The Newton-Kantorovich-type algorithm is used to solve the obtained operator equations. The approach is applied to the inverse problems in chemical kinetics [1], developmental biology [2], and air quality studies for the Novosibirsk city agglomeration [3].

The work is supported by RFBR 19-07-01135 (inverse coefficient problems) and 19-47-540011 (Novosibirsk city air quality scenarios)

[1] Penenko, A. *A Newton-Kantorovich Method in Inverse Source Problems for Production-Destruction Models with Time Series-Type Measurement Data // Numerical Analysis and Applications, Pleiades Publishing Ltd, 2019, 12, 51-69*

[2] Penenko, A.; Zubairova, U.; Mukatova, Z. & Nikolaev, S. *Numerical algorithm for morphogen synthesis region identification with indirect image-type measurement data // Journal of Bioinformatics and Computational Biology, World Scientific Pub Co Pte Lt, 2019, 17, 1940002*

[3] Penenko, V. V.; Penenko, A. V.; Tsvetova, E. A. & Gochakov, A. V. *Methods for Studying the Sensitivity of Air Quality Models and Inverse Problems of Geophysical Hydrothermodynamics // Journal of Applied Mechanics and Technical Physics, Pleiades Publishing Ltd, 2019, 60, 392-399*

**Z. Mukatova, A. Penenko,  
A. Bobrovskih,  
U. Zubairova, A. Doroshkov**

### **Numerical study of the inverse coefficient problem for the base model of the plant cell antioxidant system**

In this talk the inverse coefficient problem for the production-destruction type model is considered. Solving nonlinear inverse problems requires the development of efficient numerical algorithms. For the numerical solution of such problems, variational algorithms are often used, which are based on minimizing a certain cost functional, but their essential disadvantage is the complexity of parallelization. Earlier in [1, 2], an approach was used, which consists in reducing the inverse problem to a matrix equation using sensitivity operators constructed from an ensemble of solutions of adjoint problems. The objective of the work is to apply this approach to the study of the basic model of the antioxidant system of a plant cell. The system includes 7 classes of enzymes and low molecular weight antioxidants. The problem is to find the kinetic parameters of the reactions taking place based on the concentration measurements. The results of numerical experiments are presented.

The work was supported by RFBR 19-07-01135.

*I. A.V. Penenko. A Newton-Kantorovich method in inverse source problems for production-destruction models with time series-type measurement data. Numerical Analysis and Applications, 12(1):51–69, jan 2019.*

2. A. Penenko, U. Zubairova, Z. Mukatova, S. Nikolaev. Numerical algorithm for morphogen synthesis region identification with indirect image-type measurement data. *Journal of Bioinformatics and Computational Biology*. Vol. 17, No. 1 (2019) 1940002.

## **E. N. Aristova**

### **Hermitian characteristic scheme for nonhomogeneous linear transport equation**

The interpolation-characteristic scheme for the numerical solution of the inhomogeneous transport equation is constructed. The scheme is based on Hermite interpolation to reconstruction the value of unknown function at the point of intersection of the backward characteristic with the cell edges. Hermite interpolation to regeneration the values of the function uses not only the nodal values of the function, but also values of its derivative. Unlike previous works, also based on Hermitian interpolation, the differential continuation of the transport equation is not used to transfer information about the derivatives to the next layer. The relationship between the integral means, nodal values and derivatives according to the Euler-Maclaurin formula is used. The third-order convergence of the difference scheme for smooth solutions is shown. The dissipative and dispersion properties of the scheme are considered on numerical examples of solutions with decreasing smoothness.

## **A. Favorskaya**

### **Assessment of seismic stability using a grid-characteristic method and analysis of wave phenomena**

The seismic stability of structures as a result of intense natural and man-made impacts is the subject of interest and advanced fundamental research. The seismic stability of structures as a result of intense natural and man-made impacts is the subject of interest and advanced fundamental research. The use of various modifications of the grid-characteristic method for assessing the seismic resistance of various objects is considered. Comparison of various modifications of this numerical method with each other is performed. Also the use of analysis of simulated wave phenomena to assess the localization of fracture regions is discussed. Various types of objects are considered: residential buildings, nuclear power plants, etc.

This work was supported by the Russian Science Foundation, grant no. 17-71-20088.

## **N. I. Khokhlov**

### **On increasing the accuracy order of the grid-characteristic method for the case of a system with variable coefficients**

The solution of systems of partial differential hyperbolic equations is required for numerical modeling of a wide range of problems in mathematical physics. One of the areas where this kind of problem arises is the modeling of the propagation of dynamic wave disturbances in solid deformable bodies. When modeling in models with a complex

heterogeneous structure, it is necessary to correctly take into account the multitude of contact surfaces at the interfaces between different media with different characteristics of the medium. In this case, a system of equations with variable coefficients arises. In this paper, we consider a novel approach based on a grid-characteristic method that allows numerically solving systems of hyperbolic equations for the case of a piecewise constant matrix. One-dimensional acoustics are considered, two approaches are shown for taking into account the interface between media with the first order of accuracy and increased order of accuracy. A series of test calculations is given.

This work was supported by the Russian Foundation for Basic Research, project no. 18-31-20041 mol\_a\_ved.

**A. A. Kozhemyachenko,  
I. Petrov**

### **Calculation of vibrations of railway structures by the grid-characteristic method**

Studying the features of the wheel-rail system and modeling the movement of trains in the bridge zone are important problems in the field of railway safety. We used the grid-characteristic method on structured grids to solve these problems. The bridge structure is presented in the form of a layered continuous linear-elastic medium. Complete system equations describing the state of a continuous linear-elastic medium are solved. Images of the dynamic pressure distribution on the bridge structure from train are obtained. The characteristic propagation time of wave responses from the layers of bridge is

estimated. A comparative analysis is presented for different positions of the contact spot in the wheel-rail system. The influence of damping in the rail base on the distribution of pressure along the bridge structure from the wheel-rail system is considered.

The reported study was funded by RFBR and JSC Russian Railways according to the research project № 17-20-01096.

**Y. Poroshyna, P. Utkin**

### **Mathematical modeling of pulsating detonation wave in the shock-attached frame using two-stage chemical kinetics model**

For the numerical study of a pulsating detonation wave using a two-stage kinetics model of chemical reactions in the shock-attached frame, a new numerical algorithm is proposed. For the four known modes of detonation wave propagation, the effect of the approximation order of the proposed numerical algorithm, the length of the computational domain, the grid resolution, and the type of the far-field boundary condition on the simulation results is analyzed in the framework of this model. The character of pulsations is compared with the numerical results obtained by a number of other authors.

**V. Golubev, A. Favorskaya**

### **The study of wave phenomena in heterogeneous environments**

The report is devoted to the application of the developed method for studying wave phenomena using computational experiments to various problems of practical importance. The wave phenomena arising from the scattering of

transverse waves at the interface between elastic and acoustic media are investigated. We also studied the response from a transverse plane wave when it falls on a crack located along the wave front moving direction. A classification of multiple waves and a method for studying the properties of materials based on it are proposed. For all the problems considered, analytical expressions are obtained, which can be further used to develop new methods of seismic exploration and ultrasonic non-destructive testing.

The reported study was funded by RFBR according to the research project № 18-31-20063.

**V. Aksenov, A. Vasyukov,  
K. Beklemysheva**

### **Verification of numerical model for thin composite membranes by study of its spectral properties.**

A finite-element model of composite membrane dynamics is being developed. The numerical scheme supports arbitrary elasticity tensor and complex unstructured grids and allows for simulation of wave-propagation processes. The capabilities of available experimental equipment allow only to track displacement variation through time in a certain point of the specimen. Synchronization of measurements in different points seems hardly possible. Due to these constraints, a semi-analytical verification procedure is proposed. It is based on comparison of the model's eigenvalues to the frequencies acquired from the Fourier transform of the experimental signal. The procedure is tested either on the analytical spectrum of an isotropic specimen, which is known from theory, or on actual experimental data

for a composite with unknown elastic parameters

**V. Furgailo, A. Ivanov,  
N. Khokhlov**

### **Research of techniques to improve the performance of explicit numerical methods on the CPU**

In this talk will be considered improve performance of explicit numerical methods on an example of solve acoustic equation in three dimensional space by the finite difference time domain method. For this, in conjunction with parallel computing, we used CPU capabilities like SIMD-computing with AVX-instructions and hierarchical structure of the memory of the CPU caches to optimize data locality. For data locality was used the method of changing order of traversal on the iteration space – loop tiling. That's why we will consider in more detail different variation of using loop tiling for four-dimensional (XYZ space with time axis T) stencils computation to improve performance of multi-threaded calculation by explicit numerical methods.

The reported study was funded by RFBR according to the research project No. 18-07-00914 A.

**P. Stognii**

### **Modelling of seismic waves spread in geological media with hydraulic fracturing by the grid-characteristic method**

In this work, the results of modelling the seismic waves spread in geological media with hydraulic fracturing by the grid-characteristic method are presented. The

wave pictures and seismogramms demonstrate the possibility of detecting seismic reflections from the fracture for the given formulation of the problem.

## **A. Gordov, N. Khokhlov**

### **On the method of applying integral equations in modeling seismic problems**

This paper considers the use of integral equations in modeling seismic problems. The integral equation method is used in numerical modeling of the propagation of dynamic wave disturbances in heterogeneous media, including seismic exploration cases [1][2]. This approach allows to drop significantly number of calculations and decrease the size of the problem compared with the classical finite-difference method by discretizing only anomalous medium. A series of test calculations for various configurations of the anomaly and a point source with the data taken in different points of the calculation space was carried out. It was investigated the error of the classical finite-difference and integral methods. For instance, Figure 1. shows an example of one of the calculations - anomalous wave field from a point source located in the corner of the computational domain. For the integral equation exists some additional approaches, such as Born, quasi-linear and quasi-analytic approximations which are considered in this paper [3][4]. Each of them have its unique peculiarities and as a result allows you to find the balance between the speed and accuracy of calculations. Here are some results of the tested calculations. For comparison as CPU was used Intel Core i7-4820K @ 3.7GHz and Nvidia GeForce GTX 760 as GPU. For instance, for the small task of

size (51 - x, 21 - y, 21 - z) in took 0.5s, 70.8s, 6.69s and 0.6s for Fourier, Straight, Helm and CUDA implementations respectively. Which shows almost no advance of the GPU over the CPU algorithms. But for the big problems, like (201 - x, 101 - y, 101 - z) GPU shows huge advantage over the CPU – 25.7s on GPU vs 270.0s on CPU. It was acquired by using the pros of the parallel structure of the GPU and resulted in decreasing the number of calculations and better using of the memory.

The further work over this approach is still on and is supported by the Russian Science Foundation, project No. 18-71-10071.

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2. *M. Malovichko, N. Khokhlov, N. Yavich, M. Zhdanov Approximate solutions of acoustic 3D integral equation and their application to seismic modeling and full-waveform inversion // Geophys. J. Int 346 (2017) P. 318-339*

3. *M. Malovichko, N. Khokhlov, N. Yavich, M. Zhdanov Acoustic 3D modeling by the method of integral equations // Computers and Geosciences. Int 111 (2018) P. 223-234*

4. *Zdanov M.S. Integral transforms in geophysics. - New York, Berlin, London, Tokyo: Springer-Verlag, 1988. - 364 p.*



**C. A. Uribe, A. Gasnikov,  
P. Dvurechensky,  
D. Dvinskikh, E. Gorbunov,  
A. Rogozin**

### **Recent Advances in Distributed Optimization over Networks**

In this talk, we show recent results on the optimal convergence rates for distributed convex optimization problems over networks, where the objective is to minimize a sum of local functions of the nodes in the network. We provide optimal complexity bounds for four different cases, namely: the case when each function is strongly convex and smooth, the cases when it is either strongly convex or smooth and the case when it is convex but neither strongly convex nor smooth. Our approach is based on the dual of an appropriately formulated primal problem, which includes the underlying static graph that models the communication restrictions. Our results show distributed algorithms that achieve the same optimal rates as their centralized counterparts (up to constant and logarithmic factors), with an additional cost related to the spectral gap of the interaction matrix that captures the local communications of the nodes in the network. We also present extensions to time-varying networks and stochastic settings. Application examples are shown for the problem of distributed computation of Wasserstein barycenters.

**F. Stonyakin**

### **Gradient-type methods for optimization problems with adaptation to inexactness**

Some analogue of the concept of an inexact model of a convex objective function is introduced, which takes into account the possibility of errors both when defining the function itself and its gradient. For this concept, a gradient-type method with adaptive tuning of some parameters of this model is proposed and an assessment of the quality of the solution is obtained. A special class of convex nonsmooth optimization problems is considered, to which the proposed concept of an inaccurate model of objective functions is applicable. An adaptive gradient method is proposed for objective functions with some relaxation of the Lipschitz condition of the gradient satisfying the well-known Polyak-Lojasievich condition. In this case, the possibility of inexact setting of the objective function and gradient is taken into account. Adaptive choice of parameters during the method operation is performed both by the value of the Lipschitz constant of the gradient, and by the value corresponding to the error of the gradient and the objective function. The linear convergence of the method is stated up to the value associated with the error.

**A. Rogozin**

### **Accelerated Method for Decentralized Optimization on Slowly Time-Varying Networks**

We study the performance of fast Nesterov gradient method applied to decentralized distributed optimization on time-varying graphs. We analyze convergence of this

method under restrictions on frequency of communication network changes.

## D. Kamzolov

### Composite High-order Method for Convex Optimization

We propose a new class of convex optimization problem with the objective function formed as a sum of  $m+1$  functions with the different order of smoothness: non-smooth but simple with known structure, with Lipschitz-continuous gradient, with Lipschitz-continuous second-order derivative, ..., with Lipschitz-continuous  $m$ -order derivative. To solve this problem, we propose a high-order optimization method, that takes into account information about all functions. We prove the convergence rate of this method. We obtain faster convergence rates than the ones known in the literature.

## N. Tupitsa, A. Gasnikov, P. Dvurechensky

### Accelerated Alternating Minimization for Non-convex Problems

In this talk I will discuss several accelerated alternating minimization methods and will give a comparison of these methods for variety of non-convex problems such as low rank matrix completion, robust regression, phase retrieval, mixed linear regression and non-negative matrix factorization.

## P. A. Ostroukhov

### Tensor methods for minimizing the objective gradient norms

In this talk we consider the problem of minimizing convex functions, having Lipschitz  $p$ -th order derivative. We propose nearly-optimal methods, using restart technique with respect to  $\|f(x_0) - f^*\|$  and  $\|x_0 - x^*\|$ , which achieve lower complexity bounds of  $\tilde{O}\left(\varepsilon^{-\frac{2(p+1)}{3p+1}}\right)$  and  $\tilde{O}\left(\varepsilon^{-\frac{2}{3p+1}}\right)$  accordingly.

## A. Ivanova

### Numerical methods for the resource allocation problem in networks

In this paper, we consider the resource allocation problem in networks with a large number of connections that use a huge number of users. To solve this problem we proposed the following numerical optimization methods: a fast gradient method, a stochastic subgradient projecting method, an ellipsoid method, and a random gradient extrapolation method. For each method, we estimate the convergence rate. Also, we provide the descriptions of the distributed calculation of the steps of the considered methods, taking into account their application to networks.

## **S. Simonov, M. I. Belishev**

### **Wave models of some differential operators on semiaxis**

The talk provides a few examples to the new notion of a wave model of symmetric operators. The wave model is constructed via trajectories and reachable sets of the relevant dynamical system associated with the operator. The model reflects some important features of the operator and is determined by the boundary spectral and/or dynamical inverse data. The latter gives hope for its fruitful applications to inverse problems of mathematical physics.

## **A. K. Pogrebkov**

### **Singular symmetries of the Hirota difference equation: relation with the Darboux system**

We consider relation between two famous integrable equations: Hirota difference equation (HDE) and the Darboux system describing conjugate curvilinear systems of coordinates in  $R^3$ . We demonstrate that specific properties of solutions of the HDE with respect to independent variables enables introduction of an infinite set of discrete symmetries. We show that degeneracy of the HDE with respect to parameters of these discrete symmetries lead to introduction of continuous symmetries by means of specific limiting procedure. This enables consideration of these symmetries on equal terms with the original HDE independent variables. In particular, integrable equation where continuous symmetries of the HDE serve as independent variables is the the Darboux system. We consider some intermediate cases as well as relation of

these results with the Direct and Inverse problems.

## **M. Pavlov**

### **New Class of Two-Dimensional Integrable Linear Equations of Second Order**

In this talk we present a new class of two-dimensional integrable linear equations of second order. We construct infinitely many particular solutions. The simplest example: ideal gas dynamics system written in Euler and in Lagrangian coordinates. Two new examples: two layer fluid motion and a rotating water around a cylinder.

## **V. Nazaikinskii, L. Kuzmina, Y. Osipov**

### **On a Deep Bed Filtration Problem with Finite Blocking Time**

We consider an initial-boundary value problem for a simple semilinear filtration equation with nonunique characteristics and prove that uniqueness nevertheless holds for the solution of this problem. The solution is then constructed by quadratures.

## **T. Novikova**

### **Solution of the inverse problem in Mueller polarimetry for the metrology of diffractive optics**

The fabrication of optical security holograms by nanoimprint process starts with the creation of master diffraction gratings. The metrology of this step (i.e. control of the ridge width, groove depth and symmetry of the profile) is crucial for controlling the intensities of diffracted orders and achieving a desirable optical

effect. Submicron photoresist 1D master gratings were measured by a spectral Mueller polarimeter [1] in visible wavelength range in reflection at conical mounting. Experimental zeroth-order Mueller matrix spectra were simulated by rigorous coupled wave analysis algorithm. From electromagnetic reciprocity theorem it follows that Mueller matrix of symmetric grating is invariant under transposition. The lack of grating profile rotational symmetry violates the reciprocity and breaks the symmetry of corresponding Mueller matrix. This phenomenon was observed experimentally and simulated numerically at cross-polarization conditions. We demonstrated that optical non-reciprocity of the diffraction gratings can be used for an unambiguous detection of grating profile asymmetry.

[1] T. Novikova, P. Bulkin, V. Popov, B. Haj Ibrahim, A. De Martino, "Mueller polarimetry as a tool for evaluation of diffraction grating profile asymmetry", *J. Vac. Sci. Technol. B*, 29(5) 051804 (2011).

## M. Rakhel, V. Danilov

### Construction of fundamental solution to degenerate parabolic equation

We construct an asymptotics of fundamental solution of the Cauchy problem for the degenerate parabolic

$$\text{equation } \begin{cases} \frac{\partial G}{\partial t} - hx^2 \frac{\partial^2 G}{\partial x^2} = 0 \\ G|_{t=0} = \delta(x - \xi) \end{cases}. \text{ First, we}$$

determine the symbol of the fundamental solution  $V(x, t, h, y, \xi)$  which is the solution of the Cauchy problem with a

smooth initial condition

$$\begin{cases} \frac{\partial V_\beta}{\partial t} - hx^2 \frac{\partial^2 V_\beta}{\partial x^2} = 0 \\ V_\beta|_{t=0} = e^{-\frac{\beta(x-\xi-y)^2}{2h}} \end{cases}$$

In [1], the formula

$$G_\beta(x, t, h, \xi) = \frac{1}{\sqrt{\pi h}} \left( V(x, t, h, h \frac{\partial}{\partial \xi}, \xi) e^{-\frac{\xi^2}{2h}} \right) \Big|_{\xi=0}$$

was proved, where passing to the limit, we obtain

$$G(x, t, h, \xi) = \lim_{\beta \rightarrow -1-0} G_\beta(x, t, h, \xi)$$

Problem (2) is associated with a special Lagrangian manifold  $(x, y, p_x, p_y)$  and the Hamiltonian system

$$\begin{cases} \dot{x} = H_p(x, p_x), & x|_{t=0} = x_0 \\ \dot{p}_x = -H_x(x, p_x), & p_x|_{t=0} = \beta(x_0 - y - \xi) \\ \dot{y} = 0, & y|_{t=0} = y \\ \dot{p}_y = 0, & p_y|_{t=0} = -\beta(x_0 - y - \xi) \end{cases}$$

In turn, this system is associated with the symplectic structure determined by the form  $\omega = p_x dx - p_y dy$  similar to the

form that arises in the theory of integral Fourier operators. We show that the solution of problem (1) has the form  $G(x, t, h, \xi) = \delta(x) + G_1(x, t, h, \xi)(1 + O(h))$

where  $G_1(x, t, h, \xi)$  is a continuous function smooth outside some curves on  $(\mathbb{R}_t^+ \times \mathbb{R}_x)$ . The obtained results are

generalized to the case of more general "parabolic" Hamiltonians

$$H(x, p) = \sum_{i,j=1}^n a_{ij}(x) p_i p_j, \quad x \in \mathbb{R}^n \quad \text{that}$$

are degenerate on a smooth surface  $\Gamma \subset \mathbb{R}_x^n$ .

[1] Danilov V.G., *A Representation of the Delta Function via Creation Operators and Gaussian Exponentials, and Multiplicative Fundamental Solution Asymptotics for Some Parabolic Pseudodifferential Equations, Russian Journal of Mathematical Physics vol. 3 no. 1 (1995), 25-40*

**D. S. Minenkov,  
S. Dobrokhotov,  
V. Nazaikinskii**

### **Asymptotics on 2D nonlinear runup over slopping bottom**

We consider the two-dimensional shallow water equations over slopping bottom  $D(x) = x$  and study the Cauchy problem with localized initial data. This problem can describe tsunami waves and initial conditions correspond to piston model of tsunami generation. We construct formal asymptotics, using the Carrier-Greenspan transform and asymptotics of linearized problem near the shore. The linear asymptotics was recently obtained using Maslov canonical operator in extended phase space. Final formulas allow efficient computer realization and fast computations.

**A. Voloshin, A. Konyukhov,  
L. Pankratov**

### **Homogenization of chemical reactive flow in double porosity media**

We study chemical reactive two-phase flow of immiscible incompressible fluids

in a periodic double porosity reservoir. The medium is made of two superimposed continua, a connected fracture system and an  $\varepsilon$ -periodic system of disjoint matrix blocks. We assume that the permeability of the blocks relative to the permeability of the fissures is of order  $\varepsilon^2$ , while the porosities are of the same order. The model consists of the equations derived from the mass balance of both fluids along with the Darcy-Muskat and the capillary pressure laws containing the source terms corresponding to the chemical reactions in the reservoir. Due to the reaction both porosity and permeability of the matrix are also functions of time. The mathematical model is given by a coupled system of two-phase flow equations and the equations on the concentrations of reacting components. By the method of formal asymptotic expansions and by passing to the limit as  $\varepsilon \rightarrow 0$ , we derive the global behavior of the model and obtain the global model of the reactive flow. It is shown that the homogenized model can be represented as the usual equations of a reactive immiscible incompressible two-phase flow except for the addition of new source terms calculated by a solution to a local problem in the matrix block. These source terms reveal the nonlocal behavior of the model with respect to the time variable.

This work was supported by the Russian Foundation for Basic Research (grant No. 19-01-00592).

**A. Astrakhantseva**

### **Optimal control of endovenous laser ablation**

This paper deals with a inhomogeneous initial-boundary value problem for equations of complex, radiative-

conductive, heat transfer with moving sources. The unique solvability of this highly nonlinear problem is proven. Numerical experiments related to simulation of endovenous laser ablation are performed. The optimal control problems for this model is considered.

## R. Rawat

### Study of Phylogenetic for computational Evolution of Process, Design and Architectures

The reconstruction of the Tree of Life is a classical and Complex problem in evolutionary biology that has benefited from numerous branches of mathematics, including probability, information theory, Proof Theory, combinatorics, and geometry. Additionally, advances in computer technology Design and architecture such as parallel, Centralized and distributed computing, and programs that exploit them efficiently in combination with the continual development of faster search strategies promise to make even larger phylogenetic problems increasingly tractable. However, the NP-completeness of the phylogeny problem represents a fundamental limitation in efforts to unearth the tree of life. Modern DNA sequencing technologies are producing a deluge of new genetic data, transforming how we view the Tree of Life and how it is reconstructed.

## A. K. Volosova, N. Volosova, K. Volosov, D. Feliksovich

### The diagnosis of prostate cancer in rats and mens

According to the consultant, Ph. D. of medical Sciences , head of the Department

of oncological surgery of the research Institute "Urology of the Russian Federation" D. A. Roshchin, this modified model is promising to test as a prognostic tool for diagnosis, at least in two situations: first, in a detailed examination of patients in the clinic; secondly, in determining the positive shift of biological indicators of patients after surgery to the homeostatic state (HS) "on average". Denote by:  $T_s$  –Serum Testosterone Concentration [nM],  $DE(t)$  – DHT Concentration in Normal Plastatic Cell E [nM], , similarly, we denote:  $RE(t)$ –Free Androgen Receptor Concentration [nM],,  $Di(t)$  -(DHT -dihydrotestosterone) [nM],  $AE(t)$  – (DHT-activation Androgen Receptor Concentration) [nM],  $AEt(t)$  – Testosterone- activation Androgen Receptor Concentration [nM]. These functions and  $f$  are determined from a nonlinear system [1] at its fixed point (1) The case  $AE=0$ ,  $DE=0$  was discussed in [3]-5]. The solution at a fixed point has the form (2) All concentrations and  $f$  are expressed through the concentration of testosterone  $TEh$ . All equations in HS (fixed point) are satisfied except (1), from it we obtain a nonlinear algebraic equation  $H(TEh, f, rE0)=0$ . From here we find  $f=F(TEh, rE0)$ . In [1] given for men  $rE0=180$  [nM] , a  $\beta T=18.276$  [nM/h] . (3) Calculate from (2), (3) the derivative concentration of dihydrotestosterone  $dDEh(TEh)/d(TEh)$  through substituting constants-the speed of reactions in (1). It is necessary to seek treatments (catalysts), which can change the speed of reactions in the model and as a result slow down the increase of this derivative), and therefore prolong life. The hypothesis explaining the mechanism of chemotherapy action is formulated.

*I. Jain H.V., Clinton S.K., Bhinder A., Fridman A. 10.1073/pnas.1115750108*

Supporting Information,  
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5. A.K. Volosova, N.K. Volosova, K.A. *The First International Conference «Mathematical Physics Dynamical Systems, Infinite- Dimensional Analysis» Abstracts. 17-21.06.2019. Dolgoprudny, Russia. p.122-123.*

## E. Korotyaev

### Inverse problem for compactly supported potentials

We consider Schroedinger operators with compactly supported potentials on the half line. We prove the following results about discretization of inverse scattering: If we know the value of the S-matrix on some sequence of real numbers, then we can recover the potential by a new exact formula. Moreover, this mapping is the bijection.

## L. L. Frumin

### New Approaches to Coding Information using Inverse Scattering Transform

In this talk new approaches to coding optical line information using Inverse

Scattering Transform is described. A signal modulation of kernel of the Gelfand-Levitan-Marchenko equations for the Nonlinear Schroedinger equation (NLSE) is considered, that offers the advantage of a relatively simple decoder design. An approach is presented based on exploiting the general N-soliton solution of the NLSE for simultaneous coding of N symbols involving  $4 \times N$  coding parameters. Also a soliton orthogonal frequency division multiplexing method is introduced.

The work is supported by Russian Science Foundation (RSF 17-72-30006), and partially by Russian Ministry of Science and Education (Project No 1201364502).

## M. M. Malamud

### To the spectral theory of infinite quantum graphs

Several spectral properties of infinite quantum graphs will be discussed. Our central abstract result establishes a close connection between spectral properties of a quantum graph and the corresponding properties of a certain weighted discrete Laplacian on the underlying discrete graph. Among these properties are selfadjointness, deficiency indices, discreteness of spectrum, semiboundedness, non-negativity, finiteness of negative spectrum, etc. In particular, we will discuss several self-adjointness results including a Gaffney type theorem. We also investigate the problem of lower semiboundedness, prove several spectral estimates (bounds for the bottom of spectra and essential spectra of quantum graphs, CLR-type estimates) and study spectral types.

The talk is based on joint results with P.Exner, A. Kostenko, and H. Neidhardt

## **V. Mikhaylov, A. Mikhaylov**

### **Dynamic inverse problem for special system associated with Jacobi matrices and classical moment problems.**

We consider Hamburger, Stieltjes and Hausdorff moment problems, that are problems of the construction of a Borel measure supported on a real line, on a half-line or on an interval  $(0,1)$ , from a prescribed set of moments. We propose a unified approach to these three problems based on using the auxiliary dynamical system with the discrete time associated with a semi-infinite Jacobi matrix. It is shown that the set of moments determines the inverse dynamic data for such a system. Using the ideas of the Boundary Control method for every  $N \in \mathbb{N}$  we can recover the spectral measure of a  $N \times N$  block of Jacobi matrix, which is a solution to a truncated moment problem. This problem is reduced to the finite-dimensional generalized spectral problem, whose matrices are constructed from moments and are connected with well-known Hankel matrices by simple formulas. Thus the results on existence of solutions to Hamburger, Stieltjes and Hausdorff moment problems are naturally given in terms of these matrices. We also obtain results on uniqueness of the solution of moment problems, where as a main tool we use the Krein-type equations of inverse problem.

## **N. Saburova**

### **Invariants for Laplacians on periodic graphs**

We consider a Laplacian on periodic discrete graphs. Its spectrum consists of a finite number of bands. In a class of periodic 1-forms, i.e., functions defined on edges of the periodic graph, we introduce a subclass of minimal forms with a minimal number  $\mathcal{I}$  of edges in their supports on the period. We show that the number  $\mathcal{I}$  is an invariant of the periodic graph and estimate the Lebesgue measure of the Laplacian spectrum in terms of this invariant. The proof is based on a specific decomposition of the Laplacian into a direct integral in terms of minimal forms, where fiber Laplacians (matrices) have the minimal number  $2\mathcal{I}$  of coefficients depending on the quasimomentum. In addition, we consider an inverse problem: we determine necessary and sufficient conditions for matrices depending on the quasimomentum on a finite graph to be fiber Laplacians.

This is a joint work with Korotyaev E.L. from St. Petersburg State University.

## **S. Agapov**

### **On first integrals of Hamiltonian systems on the 2-torus.**

We consider Hamiltonian systems related to geodesic flows (including magnetic ones) and natural mechanical systems on the 2-torus and study the question of their integrability. Generally speaking, this problem reduces to the search for an additional first integral which is independent on the Hamiltonian. The different questions related to local and



global existence of such integrals will be discussed.

This talk is based on joint results with M. Bialy, A.E. Mironov, A.A. Valyuzhenich.

## **A. Badanin**

### **Third order operator for the good Boussinesq equation on the circle.**

In this talk we consider the non-self-adjoint third order differential operator, where the coefficients are real and periodic. We obtain the results needed to solve the Dubrovin equation for the good Boussinesq equation on the circle.

This is a joint work with Prof E.Korotyaev from S-Petersburg State University.

## **P. G. Grinevich, P. Coppini, P. Santini**

### **The effect of a small loss or gain in the periodic NLS anomalous wave dynamics**

We continue to study analytically the anomalous waves periodic Cauchy problem for the focusing Nonlinear Schrodinger equation. We present explicit analytic formulas describing the effect of small/gain on the recurrence of the anomalous waves in the case of one unstable mode. It turns out that very small loss or gain can essentially change the character and the statistics of these recurrence.

In particular, we analytically explain the results of numeric simulations from the paper by O. Kimmoun, H.C. Hsu, H. Branger, M.S. Li, Y.Y. Chen, C. Kharif, M. Onorato, E.J.R. Kelleher, B. Kibler, N. Akhmediev, A. Chabchoub (2016).

## **V. Dryuma**

### **On geometric properties of the Navier-Stokes equations**

With the Navier-Stokes system of equations the Ricci-flat 14-dim Riemann space is associated. Geometrical properties of the space are studied. In particular the parameters of Beltrami of corresponding metrics are used for construction of solutions of the system.

## **L. V. Bogdanov**

### **Matrix extension of the Manakov-Santini system and integrable chiral model on Einstein-Weyl background**

It was demonstrated recently [Dunajski, Ferapontov and Kruglikov (2014)] that the Manakov-Santini system describes a local form of general Lorentzian Einstein-Weyl geometry. We introduce integrable matrix extension of the Manakov-Santini system and show that it describes (2+1)-dimensional integrable chiral model in Einstein-Weyl space. We develop a dressing scheme for the extended MS system and define an extended hierarchy. Matrix extension of Toda type system connected with another local form of Einstein-Weyl geometry is also considered.

## **A. Demidov**

### **Moutard transforms and Cauchy problem for an elliptic equation. Explicit formula of the solution in the case analytical data.**

The solution of the Cauchy problem for an elliptic equation is presented in the form of trigonometric serie with coefficients

explicitly expressed through the analytical data of the problem

## **E. Shifrin**

### **Aerodynamic Designing the Laval Nozzle for Real Gas**

The method of aerodynamic designing based on the Chaplygin transformation into the hodograph-plane is being generalized onto stationary, potential, plane-parallel and axially symmetric flows of real (imperfect) gases taking place at high temperatures and pressures. As an example, aerodynamic designing the Laval nozzle of the rocket engine with direct sonic line is considered.

## **G. B. Sidelnikov, A. Tarasov**

### **Perspectives of Inverse Scattering Transform in the coherent optical transmission**

The existing algorithms for fiber nonlinearity compensation in optical links almost reach the performance limit. The more effective approaches are needed if we want further channel capacity increasing. The inverse scattering transform (IST) is considered as the most promising one. Despite the comprehensive investigations in this directions the IST based techniques are still far from commercial usage. Such problems as huge complexity, discrete spectrum finding problem etc., are obstacles for practical usage and become scientific and engineering challenge.

**FOR NOTES**

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