Memorial of Yulia Petrova

Contents

1 Personal Data

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2 Biography

2.1 Short Biography

I was born in Ukhta, USSR in 1991. In high-school time I frequently was the winner of city olympiads in mathematics, physics, chemistry and informatics. Several times I was among the the three winners of math olympiad of republic level (Republic of Komi, Russia).

In 2008 I enrolled as a student in the program "Mathematics" at the department of Mathematics and Mechanics of St. Petersburg State University — the second largest University in Russia. In 2013 I got degree "Specialist in Mathematics" and enrolled for PhD studies with specialization in mathematical physics. My scientific advisor was Prof. Alexander Nazarov.

In 2012-2017 (during Bachelor-PhD studies) I was teaching olympiad mathematics in "Formulo de Integreco", International educational center for gifted high-school students. I participated in 7 winter and summer Russian and international camps. Also from 2014 till 2017 taught online courses in olimpiad maths for school students from non-capital regions of Russia.

In 2009 I defended Ph.D. thesis "Exact L_2-small ball probabilities for the finite-dimensional perturbations of the Gaussian processes" in the junction of stochastic processes and spectral theory of operators. This work was highly appreciated by Russian Mathematical Society. I was a winner of 22nd Möbius Contest in Moscow and also received the award for young mathematicians of St. Petersburg Mathematical Society – a very prestigious prize, winners usually become extraordinarily researchers, two of them are Fields medal winners.

After PhD defense I got a “Gazprom-Neft” scholarship and became a postdoc at Chebyshev Laboratory (St. Petersburg, Russia) doing research in the area of nonlinear PDEs describing fluid flow in porous media and participating in a long-term industrial project with petroleum company “Gazprom-Neft”. The project was devoted to Enhanced Oil Recovery (EOR) methods, and our main focus was on chemical flooding (injection of surfactants, polymers etc). We successfully finished six projects, and I got an experience of working in a big multidisciplinary team (30 people, among them mathematicians, physicists, chemists, engineers). As a result of this collaboration we have a patent, SPE conference paper, several published papers in the leading journals.

In June 2021 I became a postdoc of excellence at IMPA (Instituto de Matematica Pura e Aplicada), Rio, Brazil, at the Fluid Dynamics Group and Centro PI (Projetos e Inovação). During the postdoc I broadened my research profile in hyperbolic conservation laws working with Prof. Dan Marchesin and Prof. Bradley Plohr — big experts in hyperbolic problems. During my stay at IMPA I also got interested into dynamics of partial differential equations, in particular the rigorous justification of the viscous/gravitational fingering phenomenon. Jointly with Prof. Sergey Tikhomirov we introduce toy models of fingering, study the relations between them and look for travelling wave solutions. In general, I am inspired by fluid dynamics problems coming from real-life phenomena.

Married, no kids.

2.2 Education

2018	Ph.D. in Mathematics and Physics. St. Petersburg State University. Title: “Exact L_2-small ball probabilities for the finite-dimensional perturbations of the Gaussian processes”. Scientific Advisor: Alexander Nazarov
2013	Specialization degree in mathematics. St. Petersburg State University Scientific Advisor: Alexander Nazarov

2.3 Work Experience

Postdocs	
since 06.2021	IMPA, Postdoc of excellence. Researcher in the Fluid Dynamics group. Mentor: Dan Marchesin. Researcher in Centro PI (Projetos e Inovação) IMPA
12.2018 – 05.2021	Chebyshev Laboratory at St. Petersburg State University, Postdoc. Participart of industrial projects with company “Gazprom-Neft”

Teaching	
09.2018 – 06.2021	Assistant at Department of Mathematics and Computer Science St. Petersburg State University, Russia
09.2014 – 06.2018	Assistant at Department of Mathematics and Information Technology, St. Petersburg Academic University, Russia
09.2012 – 06.2015	Assistant at Institute of Physics, Nanotechnology and Telecommunications, St. Petersburg Polytecnic University, Russia
06.2012 – 06.2017	Teaching *Olympiad Mathematics* in “Formulo de Integreco”, International educational center for gifted high-school students. Russia.

3 Research

3.1 Publication List

11. (with B. Plohr, D. Marchesin)
Vanishing adsorption admissibility criterion for contact discontinuities in the polymer model.
arXiv:2211.10326

10. (with F. Bakharev, A. Enin, N. Rastegaev)
Impact of dissipation ratio on vanishing viscosity solutions of the Riemann problem for chemical flooding model.
arXiv:2111.15001. Accepted to Journal of Hyperbolic Differential Equations.

9. (with F. Bakharev, A. Enin, K. Kalinin, N. Rastegaev, S. Tikhomirov)
Optimal polymer slugs injection profiles.
arXiv:2012.03114. Submitted.

8. (with F. Bakharev, A. Enin, A. Groman, A. Kalyuzhnuk, S. Matveenko, I.Starkov, S. Tikhomirov)
Velocity of viscous fingers in miscible displacement: Comparison with analytical models.
Journal of Computational and Applied Mathematics, March 2022
doi:10.1016/j.cam.2021.113808.

7. (with S. Tikhomirov, F. Bakharev, A. Groman, A. Kalyuzhnyuk, A. Enin, K. Kalinin, N. Rastegaev)
Calculation of graded viscosity banks profile on the rear end of the polymer slug.
Paper SPE-206426-MS, SPE Russian Petroleum Technology Conference, October 2021
doi:10.2118/206426-MS.

6. *L_2-small ball asymptotics for a family of finite-dimensional perturbations of Gaussian functions.*
Zapiski Nauchnykh Seminarov POMI, vol. 501. Nikitin's memorial volume, pp. 236–258, 2021. (In Russian).
English version: arXiv:1905.07804.

5. (with F. Bakharev, L. Campoli, A. Enin, S. Matveenko, S. Tikhomirov, A. Yakovlev)
Numerical investigation of viscous fingering phenomenon for raw field data.
Transport in Porous Media, 2020, pp. 1–22;
doi:10.1007/s11242-020-01400-5.

4. *On spectral asymptotics for a family of finite-dimensional perturbations of operators of trace class.*
Doklady Math., 2018, vol. 98, №1, pp. 367–369.
doi:10.1134/S1064562418050204.

3. *Exact L_2-small ball asymptotics for some Durbin processes.*
Zap. nauchn. sem. POMI, 2017, vol. 466, pp. 211–233. (In Russian)
Translated: Journal of Mathematical Sciences (USA), 2020, 244(5), pp. 842-857.
doi:10.1007/s10958-020-04657-9.

2. *Spectral asymptotics for problems with integral constraints.*
Mat. Zametki, 2017, vol. 102(3), pp. 405–414 (In Russian).
Translated: Mathematical Notes, 2017, 102(3-4), pp. 369-377.
doi:10.1134/S0001434617090073.

1. (with A. I. Nazarov)
The small ball asymptotics in Hilbertian norm for the Kac–Kiefer–Wolfowitz processes.
Teor. Veroyatnost. i Primenen., 2015, Volume 60, Issue 3, Pages 482–505.
Translated: Theory of Probability and its Applications, 2016, 60(3), pp. 460-480.
doi:10.1137/S0040585X97T987752.

3.2 Awards

2021–2023	Bolsa de Excelência at IMPA
2019	Laureat of the "Young Mathematician" prize of the St. Petersburg Mathematical Society
2018-2019	"Gazprom-Neft" Scholarship
2018	Winner of 22nd Möbius Contest in nomination"Undergraduates and graduates"
2009	Euler Fellowship for undergraduate students

3.3 Short research description

I got my PhD in 2018 under the supervision of Alexander I. Nazarov in the junction of stochastic processes and spectral theory of operators. The title of my thesis is "Exact L_2-small ball probabilities for the finite-dimensional perturbations of the Gaussian processes", which is published in papers [3–7]. Original text of phd thesis is in [14] (only in Russian).

After the defense I was a postdoc at Chebyshev Laboratory (St. Petersburg, Russia) doing research in the area of nonlinear PDEs describing fluid flow in porous media. I also participated in a long-term project with petroleum company "Gazprom-Neft". As a result of this collaboration we have a patent [12], SPE conference paper [8], published papers [1, 2] and two preprints [9, 10] (submitted). Now I continue studying this topic at the Laboratory of Fluid dynamics at IMPA and writing papers [11] (preprint), [13] (work at progress).

Fluid flow in porous media

Multiphase flows in porous media appear in many applications such as oil and gas recovery (e.g. [24]), CO_2 sequestration, hydrology, filtration, perfusion of the contrasting agent in cardiac tissue. Such processes are often described by a system of conservation laws (mass, momentum etc) with velocity obeying a Darcy's law. The general system of multiphase and multicomponent flow has many dependent variables (concentration of each phase and component, pressures, velocities) and is rather complicated, thus we consider two simplifications:

(1) multi-phase flow in one-space dimension. We are interested in existense, long-time asymptotics and stability of solutions. A detailed description of obtained results and future plans is presented below in Sec. 3.3.1.

(2) one-phase flow in multi-space dimensions. In particular, I am interested in mathematically rigorous proof of the linear growth of viscous/gravitational fingers (unstable displacement with pattern formation, see Fig.1). A detailed description of obtained results and future plans is presented in Sec. 3.3.2.

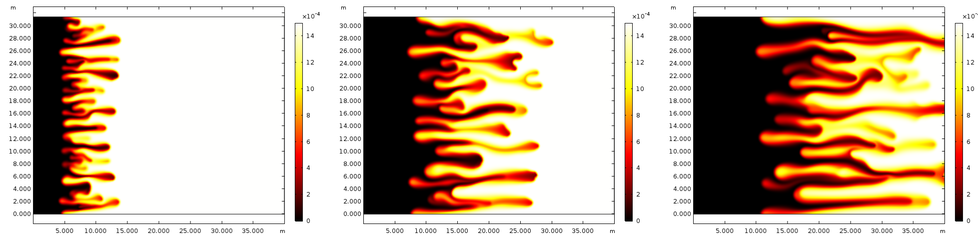

Fig. 1: Simulation of miscible viscous fingering: injection of less viscous water (black color) into a more viscous polymerized water (white color). Figures represent the growth of instability at three consecutive time moments. The process is highly nonlinear: fingers can join, split, sheild etc (see e.g. [18, 31])

3.3.1 Systems of one-dimensional PDEs describing multi-phase flow in porous media

We study the chemical flooding models that appear in petroleum engineering in the context of Enhanced Oil Recovery (EOR), e.g. injection of water with polymers/surfactants into oil reservoir.

The dimensionless form of a system of PDEs describing the injection of water with solvent into oil writes as:

$$\text{(conservation of water)} \qquad s_t + f(s,c)_x = 0, \tag{1}$$

$$\text{(conservation of solvent)} \qquad (cs + a(c))_t + (cf(s,c))_x = 0. \tag{2}$$

Here $s \in [0,1]$ — water saturation, $c \in [0,1]$ — solvent concentration, $f(s,c)$ — fractional-flow function (Buckley-Leverett function, monotone, usually S-shaped in s), $a(c)$ — adsorption term.

We are interested in the following questions:

(1a) *Admissible shock waves and solution to a Riemann problem.* In the theory of hyperbolic conservation laws one of the main challenges is to determine which weak solutions are admissible (see e.g. the classical book by Dafermos [15]). The system (1)–(2) is not strictly hyperbolic, so general theory is not applicable. We use the analogue of the vanishing viscosity criterion and say that the discontinuous solution (shock wave) is admissible if it is obtained as a limit of the travelling wave solution for the diffusive system:

$$\begin{aligned} s_t + f(s,c)_x &= \varepsilon_c (A(s,c) s_x)_x, \\ (cs + a(c))_t + (cf(s,c))_x &= \varepsilon_c (cA(s,c) s_x)_x + \varepsilon_d c_{xx}. \end{aligned} \tag{3}$$

as $\varepsilon_{c,d} \to 0$. Here $\varepsilon_{c,d} > 0$ are the dimensionless capillary pressure and diffusion; $A(s,c)$ is the capillary pressure function (bounded, separated from zero and Lipschitz continuous).

For the monotone dependence $f(s,c)$ on c the uniqueness of the vanishing viscosity solutions was proven by Johansen and Winther in [21]. For non-monotone $f(s,c)$ there are several examples when the limit may depend on the ratio of small coefficients $\varepsilon_1/\varepsilon_2$

as $\varepsilon_1 \to 0$ and $\varepsilon_2 \to 0$ (e.g. W. Shen [35]). We generalize these results and prove the Theorem under some technical assumptions.

Theorem 1 (Bakharev, Enin, P., Rastegaev [10]). *Let f be non-monotone in c: $\forall s \in (0,1)\, \exists c^*(s) \in (0,1)$:*

(A) $f_c(s,c) < 0$ for $0 < s < 1$, $0 < c < c^*(s)$, and $f_c(s,c) > 0$ for $0 < s < 1$, $c^*(s) < c < 1$.

Then there exist $0 < v_{\min} < v_{\max} < \infty$, such that for every $\kappa = \varepsilon_d/\varepsilon_c \in (0,+\infty)$, there exist unique

- *points $s^-(\kappa) \in [0,1]$ and $s^+(\kappa) \in [0,1]$;*
- *velocity $v(\kappa) \in [v_{\min}, v_{\max}]$,*

and a shock wave, connecting $u^-(\kappa) = (s^-(\kappa), 1)$ and $u^+(\kappa) = (s^+(\kappa), 0)$ with velocity $v(\kappa)$, is admissible by a vanishing viscosity criterion. Moreover, v is monotone in κ and continuous; $v(\kappa) \to v_{\min}$ as $\kappa \to \infty$; $v(\kappa) \to v_{\max}$ as $\kappa \to 0$.

The obtained shock waves are examples of undercompressive shocks, which correspond to saddle-to-saddle connections in a travelling wave dynamical system and depend on exact form of the diffusion matrix.

Future plans (work in progress): (1) we plan to get rid of technical restriction (A) in Theorem 1 and prove a theorem for a general non-monotone dependence f on c. (2) using Theorem 1 we plan to construct exact solutions to any Riemann problem, and thus prove the existence and uniqueness theorem. (3) It is of interest to find all admissible shock waves for possible degenerate capillary function $A(s,c)$, which is a more physically relevant situation.

(1b) *Existence of solution to a Cauchy problem.* Next step in analyzing the system (1)-(2) is to prove that any Cauchy problem has a unique weak solution for bounded variation (BV) initial data. For the case of zero adsorption, $a(c) \equiv 0$ this was done by Temple [36] using Glimm scheme and the so-called Temple functional. The analysis heavily relies on the exact solution to a Riemann problem. Later it was generalised to system $n \times n$ by Isaacson and Temple [20] using random choice method. Recently W.Shen considered the case with gravity [34] using front tracking approximations and Guerra and W.Shen considered the polymer model without adsorption in rough media [17] using compensated compactness argument. Nevertheless, up to my knowledge, none of these approaches is proved to work for the system with adsorption, $a(c) > 0$, so it could be a good idea to think in this direction.

(1c) *Validation of Isaacson-Glimm admissibility criterion.* The results can be found in a preprint [11], joint work with D. Marchesin and B. Plohr. Consider $a(c) \equiv 0$, then all shock waves are contact discontinuities and vanishing viscosity criterion doesn't work anymore. In [19] Isaacson and Glimm used the following criterion

Definition (KKIT entropy condition)**.** *The contact discontinuity, connecting states U_- with U_+, is admissible if c is continuous and monotone along the sequence of contact curves, connecting U_- and U_+.*

They proved that under the KKIT criterion the solution to a Riemann problem exists and is unique. In [11] we propose a more physically motivated criterion and prove that it gives the same set of solutions:

Definition (Vanishing adsorption admissibility criterion)**.** *The contact discontinuity, connecting the states U_- with U_+, for the model* (1)-(2) *for $a(c) \equiv 0$ is admissible provided it is the L^1_{loc} limit of a family of admissible solutions of the system* (1)-(2)*, as* $\max a(c) \to 0$.

Theorem 2 (P., Marchesin, Plohr [11])**.** *The set of admissible Riemann solutions for the model* (1)-(2) *is the same for the KKIT entropy condition and the vanishing adsorption admissibility criterion.*

(1d) *Stability of the travelling wave solutions.* Theorem 1 shows the existence of special travelling wave solutions for the diffusive system (3). The natural question is to study their stability (linear, nonlinear, asymptotic). Our plan is to analyze their stability using different approaches: Evans function approach, theory of K. Zumbrun for stability of undercompressive shocks (see e.g. [28]).

(1e) *Extension to three-phase flow.* It is of interest to consider a three-phase model (oil, gas and water with dissolved chemicals), find admissible shock waves, construct solution to a Riemann problem, prove the existence of weak solutions to any Cauchy problem etc. The travelling wave dynamical system will be three-dimensional, which will make the analysis of admissible shock waves much more complicated than the proof of Theorem 1 (based mainly on phase plain analysis).

3.3.2 Viscous and gravitational fingering

Consider an injection of water into polymerized water in porous media either in two dimensional strip $\Omega = [-1,1]\times\mathbb{R}$ or in $\mathbb{R}^2$. The displacement can be described by the incompressible porous medium (IPM) equation on the polymer concentration c (see e.g. [32]):

$$\text{(conservation of species)} \qquad c_t + \vec{u}\cdot\nabla c = \varepsilon\Delta c, \tag{4}$$

$$\text{(incompressibility condition)} \qquad \operatorname{div}(\vec{u}) = 0, \tag{5}$$

coupled with Darcy's law, a relation between velocity $\vec{u}$ and pressure p, which takes into account either viscosity or gravity:

$$\text{(viscous Darcy's law)} \qquad \vec{u} = -m(c)\nabla p, \tag{6}$$

$$\text{(gravitational Darcy's law)} \qquad \vec{u} = -\nabla p - (0,c). \tag{7}$$

Here $c = c(x,y,t) \in [0,1]$ — polymer concentration, $\vec{u}$ — velocity, p — pressure, $\varepsilon \geq 0$ — diffusion coefficient (usually small), $m(c)$ — mobility of water in presence of polymer (a decreasing function of c).

Many laboratory and numerical experiments show the unstable displacement and formation of patterns called viscous / gravitational fingering (see Fig. 1; the classical overview by Homsy [18] and a recent one by Scovazzi et al. [33]). Also the experiments show the linear growth of the mixing zone for moderate time regimes (see [31]; see also our numerical works on miscible flow [2], immiscible flow [1] and applications to real-world problems [8], [9]). There exist various empirical models (Koval model [23], Todd-Longstaff [37]), that tend to explain the linear growth and find the exact value of velocity by fitting the experimental data with simplified models. Nevertheless, up to my knowledge, even nowadays no mathematically rigorous result concerning the exact rate of the fingers growth is known for the system (4)-(5) neither with viscous law (6) nor with gravitational (7).

This situation determines our goal. We aim at introducing a simplified model closely related to (4)-(7), where one can prove the linear growth of the mixing zone and find exact velocity of growth. Long-term goal is to investigate the same questions for the original model (4)-(7). Currently we are interested in:

(1) *Transverse flow equilibrium model (TFE).* It was originally introduced by [38] and then mathematically rigorously analyzed by G. Menon and F. Otto in [29,30] in the context of gravitational fingering and some results were obtained by Yortsos and Salin in [39] in the context of viscous fingering. A detailed description of the model and possible future directions of research are presented below.

(2) *Two-tube model.* This is work in progress with Ya. Efendiev and S. Tikhomirov [13]. We introduce a model of two convection-diffusion PDEs, that mimics the system (4), (5) and one of (6), (7) and corresponds to the displacement of fluid in a system of two tubes (or two layers). The fluid can move not only along the tube (layer) but also between them. We observe linear growth of the appearing mixing zone and are able to find explicit velocities for the case of gravitational fingering. A detailed description of obtained results and future plans are presented below.

Let us also mention that for $\varepsilon = 0$ the question of well-posedness for IPM equations remains open (global solution vs. finite-time blow-up). The recent work of A. Kiselev and Y. Yao [22] shows that if the smooth solution exists for all times, then some of it's Sobolev norms will blow-up as time goes to infinity. If there is the finite-time blow up, an interesting question is whether the solutions are spontaneously stochastic or not (see e.g. recent works of Mailybaev and Drivas [16] for ODEs). This also sounds like an interesting direction of research.

Transverse flow-equilibrium model (TFE)

Transverse Flow Equilibrium (TFE) model consists of equations (4)-(5) and Darcy's law being replaced by:

$$\text{(velocity in viscous TFE)} \qquad u = (u^1, u^2), \qquad u^2 = \frac{m(c)}{\overline{m}(c)}, \quad \overline{m}(c)(y,t) = \int_{-1}^{1} m(c(x,y,t))\,dx; \tag{8}$$

$$\text{(velocity in gravitational TFE)} \quad u = (u^1, u^2), \qquad u^2 = \overline{c} - c, \quad \overline{c}(y,t) = \int_{-1}^{1} c(x,y,t)\,dx. \tag{9}$$

Informally, these relations can be obtained by assuming the pressure $p(x, y, t) \approx p(y, t)$ and using Green's theorem. Relations (8)-(9) still represent nonlocal dependence, but in some sense "less nonlocal" than the original Darcy's law (nonlocality is only in x direction). Mathematically TFE model is easier to treat as there is no pressure in the final formulas (8)-(9).

The linear growth of the mixing zone for TFE model was proved by Menon and Otto [30]. The main ingridient is the following comparison Theorem 3. It allows to get explicit formulas on velocity of propagation, using solution of a simple one-dimensional problem (10) as a supersolution to the two-dimensional problem.

Theorem 3 (Menon, Otto [30])**.** *Consider a solution $c(x, y, t)$ of the TFE model (4), (5), (8) and a solution $c^* = c^*(y, t)$ of the one-dimensional problem*

$$\partial_t c^* + \frac{m(c^*)}{m(1)} \partial_y c^* = \varepsilon \partial_{yy} c^*, \tag{10}$$

If initially $c^*(y, 0) \geqslant c(x, y, 0)$, then for all times $t > 0$ we have $c^*(y, t) \geqslant c(x, y, t)$.

Possible directions for future research:

- well-posedness of TFE model for both $\varepsilon = 0$ and $\varepsilon > 0$ (global solution vs. finite-time blow up).
- what is the formal connection between TFE and IPM? Are they close in some sense? If yes, we could try to prove the linear growth for the IPM using the result on linear growth for TFE.

Two-tube model

This is work in progress with Ya. Efendiev and S. Tikhomirov [13]. One of the main motivations is to sharpen the result of Menon, Otto [30] and find a better estimation on velocity of propagation of the mixing zone, taking into account the flow in transverse direction. Numerically it is observed the appearance of some intermediate concentration, which our toy model with two tubes tries to explain in a rather simple setting.

Consider a "two-tube" version of gravitational fingering phenomenon (the simplest toy model): the fluid displacement happens inside two tubes ($x \in \mathbb{R}$) and the fluid can flow from one tube to the other according to the following balance laws:

$$\begin{aligned} \partial_t c_1 + \partial_x(u_1 c_1) - \varepsilon \partial_{xx} c_1 &= -(-1)^{1,2} \partial_x u_{1,2} \cdot c_{1,2}, \\ \partial_t c_2 + \partial_x(u_2 c_2) - \varepsilon \partial_{xx} c_2 &= (-1)^{1,2} \partial_x u_{1,2} \cdot c_{1,2}. \end{aligned} \tag{11}$$

where the following term corresponds to the flow between tubes:

$$(-1)^{1,2} \partial_x u_{1,2} \cdot c_{1,2} = \begin{cases} -\partial_x u_1 \cdot c_1, & \partial_x u_1 < 0, \quad \text{(fluid flows from 1st tube to the 2nd)}, \\ +\partial_x u_2 \cdot c_2, & \partial_x u_1 \geq 0, \quad \text{(fluid flows from 2nd tube to the 1st)}. \end{cases} \tag{12}$$

Here $c_1(x, t), c_2(x, t)$ is the fluid concentration in the 1st, 2nd tube; u_1, u_2 — polymer velocity in 1st, 2nd tube, $\varepsilon > 0$ — small diffusion parameter. We consider two models of fluid velocities $u_{1,2}$:

1. a "two-tube" analogue of the Darcy's law, which relates velocities $u_{1,2}$ with the pressures $p_{1,2}$ in each tube:

$$\text{(Darcy's law in each tube)} \qquad u_1 = -\partial_x p_1 - c_1, \qquad u_2 = -\partial_x p_2 - c_2, \qquad (13)$$

$$\text{(Darcy's law between tubes)} \qquad \partial_x u_1 = (p_2 - p_1)/l, \qquad \partial_x u_2 = -(p_2 - p_1)/l. \qquad (14)$$

   Here $l > 0$ is a parameter.

2. a "two-tube" analogue of TFE, simplified model:

$$\text{(TFE model for velocities)} \qquad u_1 = (c_2 - c_1)/2 \qquad u_2 = -u_1. \qquad (15)$$

Theorem 4 (P., S. Tikhomirov, Ya. Efendiev [13])**.** *Consider the system (11)–(12) with velocities defined by TFE model (15). Then there exist exactly one value of $c_1^* = -c_2^* = 1/2$ (up to change of variables $c_1 \leftrightarrow c_2$) and a velocity $v^* = 1/4$ such that the two travelling waves:*

- $c_{1,2} = c_{1,2}(x - v^*t)$, $c_{1,2}(-\infty) = c_{1,2}^*$, $c_{1,2}(+\infty) = 1$.
- $c_{1,2} = c_{1,2}(x + v^*t)$, $c_{1,2}(-\infty) = -1$, $c_{1,2}(+\infty) = c_{1,2}^*$.

are both solutions of (11)–(12), (15). See Fig. 2 for numerical evidence of such kind of solution.

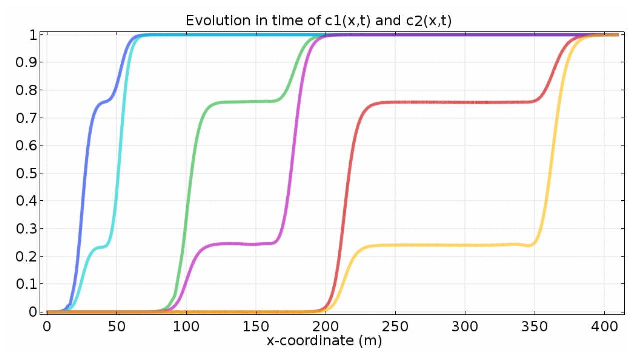

Fig. 2: Concentration of fluid c_1 and c_2 in 1st and 2nd tube, respectively, in gravitational two-tube model in three time moments. The solution forms a cascade of two travelling waves.

By using a geometric singular perturbation theory and normal hyperbolicity of invariant manifolds we plan to transfer the existence of travelling wave solutions from (15) to the case of Darcy's law (13)-(14). In particular, we hope to prove a rigorous connection between IPM and TFE in a two-tube setting in terms of travelling wave solutions as $l \to 0$. Possible directions for future research:

- Find exact velocities in a two-tube model for viscous TFE model and Darcy's law. Numerically, we observe the same kind of solutions as for gravitational case. Nevertheless, due to the presence of mobility function $m(c)$, analogous theorems are much harder to prove.
- Analyse the stability of the cascade of two travelling waves from Theorem 4.
- Generalize the model for n-tubes. Can we go to the limit as $n \to \infty$ and recover the original two-dimensional model (4),(5),(7)? Can this two / n-tubes model explain some features of the two-dimensional phenomena?

3.3.3 Small ball probabilities for Gaussian processes

I was doing research in this topic during my PhD studies at St. Petersburg State University. The full version of my phd thesis is in [14] (in Russian).

The theory of small deviations of Gaussian processes in different norms is intensively developed in last decades (see the surveys [25, 27]; for the extensive up-to-date bibliography see [26]). Given a random process $X(t)$ in some Banach space $(V, \|\cdot\|)$, the asymptotic behavior of the probability

$$\mathbb{P}\{\|X\| < \varepsilon\} \text{ as } \varepsilon \to 0$$

is called an *exact* asymptotics of small deviations (or small ball probabilities). It is a beautiful theory with wide range of techniques and applications such as accuracy of discrete approximation of random processes and the quantization problem, the calculation of the metric entropy for functional sets, the law of the iterated logarithm in the Chung form, the rate of escape of infinite dimensional Brownian motion etc.

The most explored case is that of L_2-norm, for which the eigenvalues of the covariance operator fully determine the process. The main difficulty is that the explicit formulas for eigenvalues are rarely known. That's why even in Hilbert case one usually studies the logarithmic asymptotics of small deviations, that is the asymptotics of $\ln(\mathbb{P}\{\|X\| < \varepsilon\})$.

In 2004 A. Nazarov and Ya. Nikitin considered a class of the *Green Gaussian processes*. For such processes the covariance function $G_X(s,t) \equiv \mathbb{E}X(s)X(t)$ is the Green function for an ordinary differential operator (ODE). This allows to study the asymptotics of eigenvalues using powerful methods of spectral theory of ODEs, and get the exact small ball asymptotics for a large class of the Green Gaussian processes.

In the series of papers I consider a class of the finite-dimensional perturbations of the Green processes, or generally speaking, the finite-dimensional perturbations of the Gaussian processes with known L_2-small ball probabilities. Some general theorems for one-dimensional perturbations were proved by A. Nazarov. I generalized these theorems for corresponding finite-dimensional perturbations and introduced the notions of non critical, critical and partially critical perturbations for this case. Short version of these results is published in [6], full version with proofs — in [7].

Nevertheless, the obtained general theorems do not cover a significant part of the processes of interest in probability theory and statistics. In particular these theorems can not be applied to the so called Durbin's processes. These processes appear as limiting ones when building goodness-of-fit tests of ω^2-type for testing that a sample is belonging to the family of distributions with estimated parameters. For such types of processes no general result holds, and each process needs to be considered individually.

In a joint work with A. Nazarov [3] the exact L_2-small ball asymptotics were calculated for the Kac-Kiefer-Wolfowitz processes, appearing when testing for normality with estimated mean and/or variance. The key point of the article is the developed technique of obtaining the complete asymptotic expansions of some oscillation integrals with slowly varying amplitudes. An algorithm of finding the exact asymptotics of the spectrum of the covariance operators and L_2-small ball probabilities for a class of Durbin's processes was obtained using this technique (more precisely, for the Durbin's processes corresponding to distributions with exponential tails). As an example in the paper [4] the L_2-small ball asymptotics for Durbin's processes for logistic, gamma, Laplace and Gumbel distributions were obtained.

In the paper [5] a two-parameter family of problems is considered, which appears when studying the exact L_2-small ball asymptotics of the so-called detrended processes of n-th order. In some particular cases such asymptotics were considered in the works of Ya. Nikitin with coathors, P.Deheuvels, W. Li with coathors and others. In the paper [5] the problem was first analyzed in complete generality. The connection of this problem with the problem of "sharp constants" in high-order imbedding theorems on a segment is established. Moreover, errors in some previously published works of other authors have been corrected.

Own published papers

[1] F. Bakharev, L. Campoli, A. Enin, S. Matveenko, **Y. Petrova**, S. Tikhomirov, and A. Yakovlev. Numerical investigation of viscous fingering phenomenon for raw field data. *Transport in Porous Media*, pages 1–22, 2020. https://doi.org/10.1007/s11242-020-01400-5.

[2] F. Bakharev, A. Enin, S. Matveenko, **Y. Petrova**, I. Starkov, and S. Tikhomirov. Velocity of viscous fingers in miscible displacement: Comparison with analytical models. *Journal of Computational and Applied Mathematics*, 402:113808, 2022. https://doi.org/10.1016/j.cam.2021.113808.

[3] A.I. Nazarov and **Y. Petrova**. The small ball asymptotics in Hilbert Norm for the Kac–Kiefer–Wolfowitz processes. *Theory of Probability & Its Applications*, 60(3):460–480, 2016.
https://doi.org/10.1137/S0040585X97T987752.

[4] **Y. Petrova**. Exact L_2-small ball asymptotics for some Durbin processes. *Zapiski Nauchnykh Seminarov POMI*, 466:211–233, 2017. https://doi.org/10.1007/s10958-020-04657-9.

[5] **Y. Petrova**. Spectral asymptotics for problems with integral constraints. *Mathematical Notes*, 102(3-4):369–377, 2017. https://doi.org/10.1134/S0001434617090073.

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https://doi.org/10.1134/S1064562418050204.

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[8] S. Tikhomirov, F. Bakharev, A. Groman, A. Kalyuzhnyuk, **Y. Petrova**, A. Enin, K. Kalinin, and N. Rastegaev. Calculation of graded viscosity banks profile on the rear end of the polymer slug. In *SPE Russian Petroleum Technology Conference*. OnePetro, 2021. https://doi.org/10.2118/206426-MS.

Preprints

[9] F. Bakharev, A. Enin, K. Kalinin, **Y. Petrova**, N. Rastegaev, and S. Tikhomirov. Optimal polymer slugs injection profiles. *arxiv:2012.03114*, 2021. Submitted.

[10] F. Bakharev, A. Enin, **Y. Petrova**, and N. Rastegaev. Impact of dissipation ratio on vanishing viscosity solutions of the Riemann problem for chemical flooding model. *arxiv:2111.15001*, 2021. Accepted to Journal of Hyperbolic Differential Equations.

[11] **Y. Petrova**, D. Marchesin, and B. Plohr. Vanishing adsorption admissibility criterion for contact discontinuities in the polymer model. *arxiv:2211.10326*.

Patents

[12] A. Groman, F. Bakharev, S. Tikhomirov, **Y. Petrova**, N. Rastegaev, A. Enin, and K. Kalinin. *Patent No. 2772808 C1 Russian Federation, IPC E21B 43/16, C09K 8/58. Method for enhanced oil recovery: No. 2021133106: Appl. 11/15/2021 : publ. May 25, 2022 / applicant Limited Liability Company "Gazpromneft-Technological Partnerships". – EDN WLGWAU.*

Work in progress

[13] **Y. Petrova**, S. Tikhomirov, and Ya. Efendiev. A cascade of two travelling waves in a two-tube model of gravitational fingering. *Work in progress*.

PhD thesis

[14] **Y. Petrova**. Exact L_2-small ball probabilities for the finite-dimensional perturbations of the Gaussian processes. In Russian. November 2018.
Link to full text of the phd thesis
Link to short text of the phd thesis
Link to page of PDMI with all detailes about the defense.

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3.4 Contacts of Recommendations

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Alexandr Nazarov	St. Petersburg department of PDMI, Russia	al.il.nazarov@gmail.com
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Yalchin Efendiev	Texas A&M, USA	yalchinrefendiev@gmail.com

4 Teaching

4.1 Conducted courses

2021 spring:	St. Petersburg State University (SPbSU) Faculty of Mathematics and Computer Science Problem solving classes, Bachelor (BSc) Calculus of variations for mathematicians	Materials (rus)	Students reviews
2020 fall:	SPbSU. Problem solving classes, BSc. Probability theory for mathematicians	Materials (rus)	Students reviews
2020 spring:	SPbSU. Problem solving classes, BSc. Complex analysis	Materials (rus)	Students reviews
2018-2019:	SPbSU. Problem solving classes, BSc. Calculus: I, II, III, IV semesters	Materials (rus)	Students reviews
2019 Jan:	Lecturer of the course “Random walks” in Educational Program in mathematics and computer science at “Sirius”, Sochi, Russia		
2019 Nov:	Assistant to the course “Dynamical systems” in COMSATS University Islamabad, Lahore Campus, Pakistan. ICTP-CUI Visiting Scholars Program for Training and Research in Math		
2014–2018	St. Petersburg Academic University. Problem solving classes, BSc Calculus (I, II, III, IV semesters) for physicists	Materials III sem, IV sem	
2012–2014	St. Petersburg Polytecnic University Problem solving classes, BSc. PDEs for physicists		
2012–2017	Teaching *Olympiad Mathematics* in “Formulo de Integreco”, International educational center for gifted high-school students. I participated in 7 winter and summer Russian and international camps. Also from 2014 till 2017 taught online courses in olimpiad maths for school students from non-capital regions of Russia	Materials from the camp	

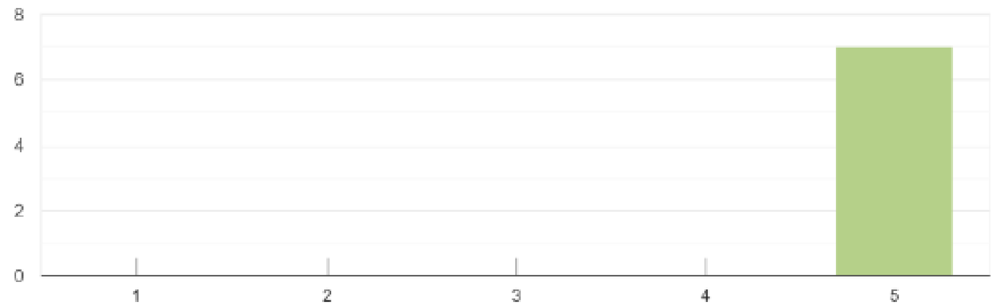
4.2 Student reviews

Calculus of variations

Practical exercises: Yu.P. Petrova

Average score: 5

Number of answers: 7



Comments:

1. Yu.P. did a lot ***more*** than enough for a teacher to prepare the lessons. Including:
- very competently planned and conducted lessons
- explained everything clearly, answered questions, wrote detailed comments on solutions of homeworks
- gave interesting, not just counting problems to solve at home
- accurately and beautifully wrote class materials and homework solution
- recorded additional (short and capacious!) videos for some homeworks
- showed relations with other disciplines (physics)
- organized a public document where it was possible to write solutions to problems posed on lectures to prepare for the test
- and much more...

Her lessons are perfect. In fact, this is the best thing that has happened to me so far during two years of study. If Yu.P. did not leave, I would really like her to teach us mathematical physics.

2. Everything is super; the teacher certainly was able to create a strong interest in the subject. There is nothing more satisfying than receiving an explanation of practical meaning from the problem of calculus of variations, rolling into the next boring differential equation.

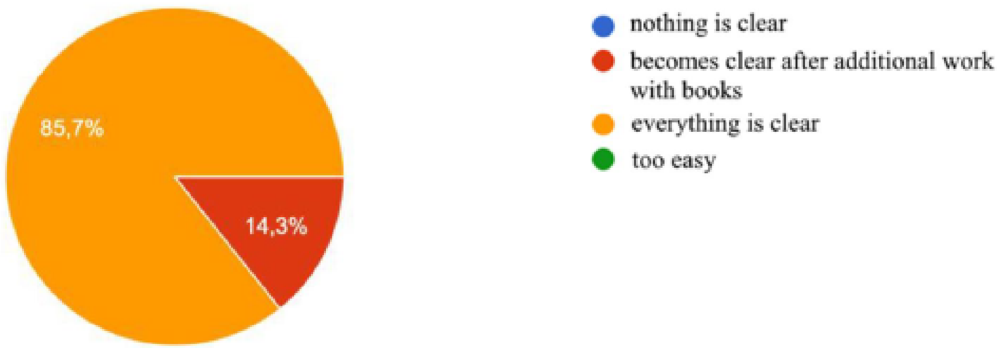
3. Practically ideal practices, although I would like more than one set of difficult problems (listochek)

4. The best teacher for all 2 years here. Yu.P. and speaks very clearly, interesting, fast and capacious, and at the same time actively involved us in the lesson. For everyone in other practices, the entire lesson is either spoken by the teacher, or we solve problems ourselves, or do homework. In fact, only Yu.P. managed to organize learning process during online lesson just as useful and good as usual offline classes.

Calculus, semester 1
Practical exercises: Yu.P. Petrova
Average score: 4.9
Number of answers: 14

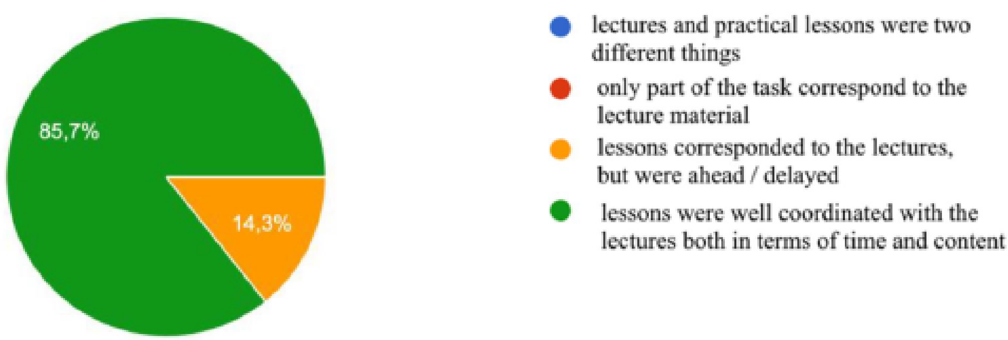
1. Clarity of practical exercises

too easy – 0
becomes clear after additional work with books – 2
everything is clear – 12
nothing is clear - 0

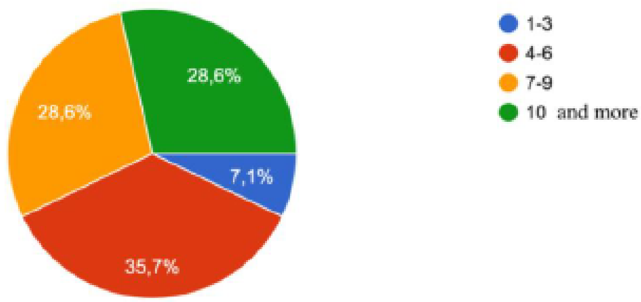


2. Consistency with lectures

lessons were well coordinated with the lectures both in terms of time and content – 12
only part of the tasks corresponded to the lecture material – 0
lectures and practical lessons were two different things – 0
lessons corresponded to the lectures, but were ahead / delayed – 2



3. How many hours does it take to complete homework
   1-3 - 1
   4-6 - 5
   7-9 - 4
   10 or more - 4



4. Speed of checking homework
   satisfied – 14
   not satisfied – 0

What did you like about practical lessons (Yulia Petrova, group 19B09) 5 answers

- Good tasks, with a gradient of difficulty. Quick check of homeworks
- Very interesting homework problems
- Everything is very interesting and everything is clear
- The teacher is always trying to help the student. Yulia Petrova tries to give hints when there are problems with solving a particular problem, which is why after solving, her the subject does not seem so difficult. Perhaps it is the practice with this teacher that closes a large number of questions on the subject
- Everything
- Very friendly atmosphere. If you do not understand from 500 times, she will explain more, give an example. And in general, Yulia Petrovna ❤

Additional comments (Yulia Petrova, group 19B09) 3 answers

- No.
- Everything is great, it's a pity she won't be with us in the second semester :(
- There is a feeling that with the departure of Yulia Petrovna, the level of calculus in our group will drop significantly, because many topics are incomprehensible without practice

4.3 Qualification works reviewing

2022:	Julia Domingues Lemos (PhD)	. IMPA	"Data-based approach for time-correlated closures of turbulence models". Scientific advisor: Alexei Mailybaev
2020:	Temirlan Abildaev (Masters)	SPbSU	"Asymptotic properties of the spectrum of integral operators of variable order" Scientific advisor: Andrey Karol
2020:	Tatyana Moseeva (Bachelor)	SPbSU	"Random sections of convex bodies" Scientific advisor: Dmitry N. Zaporozhets
2019:	Alexander Tarasov (Masters)	SPbSU	"Intrinsic volumes of ellipsoids" Scientific advisor: Dmitry N. Zaporozhets

5 Industrial Collaboration

From 2018 till 2021 I was participating in a big industrial project organized by Chebyshev Laboratory at St. Petersburg State University jointly with Russian petroleum company "Gazprom-Neft". The main topic of investigation was Enhanced Oil Recovery (EOR) and application of the advanced techniques in concrete Russian oilfields. The whole project lasted from 2018 till 2022 (5 years) with reports every half-year. The leaders from St. Petersburg State University were Sergey Tikhomirov and Fedor Bakharev; from "Gazprom-Neft" — Andrey Yakovlev and Andrey Groman.

One of the great advantages was a multidisciplinary team (mathematicians, physicists, chemists, engineers). The team at Chebyshev Laboratory consisted of 15 members of various ranks from PhD students to Professors.

We studied:

- the applicability of chemical, thermal, gaseous enhanced oil recovery methods;
- fast preliminarily estimation of effects of EOR for particular oil fields
- history matching for oil-field experiments;
- design and interpretation of laboratory experiments.

The team I was working in suggested an improvement of the chemical EOR flooding scheme (method of calculation of the graded viscosity banks), which allows to save up to 15% of chemicals. We have a joint patent with colleagues from "Gazprom-Neft".

My current topics of mathematical research (hyperbolic conservation laws and fluid dynamics of miscible viscous liquids) are based on the experience I got during this project.

6 Administrative experience

6.1 Scientific event organization

May 2021	Colloquium of Industrial projects, Chebyshev Laboratory St. Petersburg, Russia. Link

6.2 Seminar "Industrial Mathematics" in St. Petersburg

From February 2017 I was one of the organizers and a scientific secretary of the seminar "Industrial Mathematics" as a complement to the activity of research projects with industry. The seminar was actively acting till February 2022. Other organizers of the seminar are: Sergey Tikhomirov, Fedor Bakharev, Slava Borovitskiy.

Website: https://sites.google.com/view/industrial-math-seminar/main-en

Youtube: https://www.youtube.com/channel/UCkgdobthUVJbdeEtgPSzcwA

The seminar is devoted to various aspects of the application of mathematics to problems of practical importance for industry.

The first direction is associated with hydrodynamic problems, describing the movement of fluids in an oil reservoir. It includes both the study of the accompanying physical and chemical foundations and the physical and mathematical apparatus, as well as various aspects of numerical modeling.

The second direction sheds light on issues related to the geological structure of the reservoir and various approaches to its analysis, closely related to the tasks of data analysis and processing of images and signals using modern technologies.

6.3 Seminar "Applied and Computational Mathematics" at IMPA

During 2022 I was helping with organization of the seminar "Applied and Computational Mathematics" at IMPA. Seminar organizers are Alexei Mailybaev and Dan Marchesin. It was a challenging task to return to offline seminars after the Pandemic.

7 Participation in scientific events

7.1 Conferences, Workshops and Schools

Jan 2023	*(planned)* 13th Americas Conference on Diff. Equations and Nonlinear Analysis and ICMC Summer Meeting on Differential Equations. São Carlos, Brazil. Invited speaker in section "Conservation Laws and Transport Equations"	
Oct 2022	Conference IMPA 70 years & International Conference on Dynamical Systems. Celebrating the 60th Birthday of Marcelo Viana, Rio de Janeiro, Brazil	
July 2022	O.A. Ladyzhenskaya centennial conference on PDE's. St. Petersburg, Russia. Online participation. "On the impact of dissipation ratio on vanishing viscosity solutions of Riemann problems for chemical flooding models"	Poster
July 2022	Hyperbolic Balance Laws & Beyond. Magdeburg, Germany	Poster
June 2022	International Conference on Hyperbolic Problems (HYP). Malaga, Spain. Talk: "On admissibility criteria for contact discontinuities in Glimm-Isaacson model arising in chemical flooding"	Slides
May 2022	Workshop: Branching systems, reaction-diffusion equations and population models, Centre de recherches matematiques (CRM), Montreal. Online.	
Dec 2021	International conference "Probabilistic methods in analysis", in Sirius, Sochi, Russia. Talk: "Small ball probabilities for Gaussian processes"	Slides
Dec 2021	Workshop: "Nonlinear PDEs and Modelling", St. Petersburg, Russia. Talk: "Looking for exact mixing velocities in miscible displacement: two-tube model"	Slides
Aug 2021	InterPore2021. Brazilian Chapter. Talk: "Graded viscosity banks on the rear end of the polymer slug"	Slides
June 2021	InterPore2021. Online conference. Talk: "Graded viscosity banks on the rear end of the polymer slug"	Slides

Aug 2019	Third ZiF Summer School "Randomness in Physics and Mathematics". From Stochastic Processes to Networks. Bielefeld, Germany. Poster: "Exact L_2-small ball asymptotics for detrended Green Gaussian processes"	Poster
May 2019	Stochastic models II. Euler Institute, St. Petersburg, Russia. Talk: "Exact L_2-small ball probabilities for Durbin processes"	Slides
Jan 2018	The third Indo-Russian meeting in probability and statistics. Bangalore, India. Talk: "Exact small ball asymptotics in L_2-norm for finite-dimensional perturbations of Gaussian processes: spectral method"	Slides
Dec 2017	St. Petersburg winter conference on Probability Theory and Mathematical physics. PDMI-MIAN. Talk: "On exact spectral asymptotics of finite-dimensional perturbations of integral operators of trace class"	Slides
June 2017	Symposium on Probability Theory and Random Processes, St. Petersburg, Russia. Talk: "Exact L_2-small ball asymptotics for perturbations of Brownian bridge"	Slides
April 2017	International conference on partial differential equations Silkroad Mathematics Center series international conferences. Beijing, China. Poster: "Spectral asymptotics in some problems with integral constraints"	Poster
June 2016	Days of Diffraction-2016, St. Petersburg, Russia. Talk: "Spectral asymptotics in some problems with integral constraints"	Slides
May 2016	The 2nd Russian-Indian Joint Conference in Statistics and Probability. Talk: "Small ball asymptotics for detrended Green Gaussian processes"	Slides
Sept 2015	Yu.V.Linnik Centennial Conference, St. Petersburg, Russia. Talk: "The L_2-small ball asymptotics for the Kac-Kiefer-Wolfowitz processes"	
July 2015	7th St.Petersburg Conference in Spectral Theory. Talk: "Asymptotics of eigenvalues for some integro-differential operators"	Slides
July 2014	Students school on PDEs and Geometric Measure Theory, CIME, Italy	
2009–2010	XIII Diffiety School on Mathematics, Santo Stefano del Sole, Italy XII Diffiety School on Mathematics, Santo Stefano del Sole, Italy	

7.2 Invited talks at seminars

Nov 2022	Oberseminar ”Nonlinear Dynamics” at Freie Universität Berlin, Germany (joint talk with S.Tikhomirov). Seminar organizers: Bernold Fiedler, Isabelle Schneider, Eckehard Schöll, Matthias Wolfrum. Talk: “Two tube model of miscible displacement: travelling waves and normal hyperbolicity”	Slides
July 2022	Seminário de Probabilidade at Instituto de Matemática, UFRJ, Rio, Brazil. Seminar organizers: Giulio Iacobelli and Maria Eulalia Vares. Talk: “Small ball probabilities for Gaussian processes”	Slides
July 2022	Seminário Luiz Adauto de Análise/EDP at Instituto de Matemática, UFRJ, Rio, Brazil. Seminar organizer: Daniel Marroquin. Talk: “On chemical flooding models: Riemann problem solutions and viscous fingering phenomenon”	Slides
May 2022	Oberseminar “Nonlinear Dynamics” WIAS Berlin, Germany. Online. Seminar organizers: Bernold Fiedler, Isabelle Schneider, Eckehard Schöll, Matthias Wolfrum. Talk: “On the impact of dissipation ratio on vanishing viscosity solutions of Riemann problems for chemical flooding models”	Slides
12 May 2022	2-do Encontro Mulheres Matematicas do IMPA, Rio, Brazil. Online. organizers: Claudia Lorena Duarte, Daniela Paiva Penuela, Zoraida Fernandez Rico. Sessão Temática - Dinâmica dos Fluidos.	Slides
April 2022	CeMEAI seminar at ICMC/USP in São Carlos, Brazil. Seminar organizer: Tiago Pereira. Talk: “On solutions of a Riemann problem for a chemical flooding model”	Slides
April 2022	Seminar of Applied and Computational Mathematics at IMPA, Rio, Brazil. Seminar organizers: Alexei Mailybaev, Dan Marchesin. Talk: “Toy model of viscous fingering”	Slides
April 2022	Seminar on Analisis and PDE at IMPA, Rio, Brazil. Seminar organizer: Felipe Linares. Talk: “On the impact of dissipation ratio on vanishing viscosity solutions of Riemann problems for chemical flooding models”	Slides
March 2022	Seminario das Mulheres IMPA, Rio, Brazil. Seminar organizer: Zoraida Fernandez-Rico. Talk: “Small ball probabilities for Gaussian Processes”	Slides

March 2022	Centro PI seminar at IMPA, Rio, Brazil. Seminar organizers: Roberto Imbuzeiro, Paulo Orenstein. Talk: "Oil Recovery: Fundamental research and Industrial applications"	Slides
Feb 2022	Applied Math/PDE Seminar UC Davis, California, USA. Online. Seminar organizers: Blake Temple, Steve Shkoller, Sameer Iyer. Talk: "On solutions of a Riemann problem for a chemical flooding model"	Slides
Nov 2021	Gabriel Lame Chair Seminar at Chebyshev Laboratory, St. Petersburg, Russia. Online. Seminar organizer: Jean-Michel Roquejoffre. Talk: "On the impact of diffusion ratio on vanishing viscosity solutions of Riemann problems for chemical flooding models"	Slides
Oct 2021	Seminario de EDP e Matematica Aplicada. Online. Seminar organizers: Juan Limaco, Mauro Rincon, Max Souza, Marcelo Calvacanti. Talk: "Admissibilidade das descontinuidades de contato: aplicação para recuperação melhorada de petróleo" (in Portuguese)	
May 2021	Colloquium of Industrial Projects at Chebyshev Laboratory, St. Petersburg, Russia. Organizer: Sergey Tikhomirov. Talk: "On mathematical results in Enhanced Oil Recovery project" (in Russian)	Slides
Sep 2020	Seminar of Computational and Applied Mathematics at IMPA. Seminar organizers: Alexei Mailybaev, Dan Marchesin. Talk: "On the impact of diffusion ratio on vanishing viscosity solutions of Riemann problems for chemical flooding models"	
Feb 2020	Student colloquium at Chebyshev Laboratory, St. Petersburg, Russia. Talk: "Mathematical models describing the process of oil recovery"	
Jan 2020	Seminar "Industrial mathematics" at Chebyshev Laboratory, St. Petersburg, Russia. organizers: Fedor Bakharev, Sergey Tikhomirov, Yulia Petrova, Slava Borovitskiy. Talk: "On the solution of the Riemann problem for a hyperbolic system of conservation laws simulating the injection of a polymer into an oil reservoir" (in Russian)	
Feb 2018	Oberseminar, Technical University Darmstadt, Germany. Seminar organizer: Frank Aurzada. Talk: "Exact L_2-small ball probabilities for finite-dimensional perturbations of Gaussian processes"	

Jan 2018	Oberseminar Analysis, Mathematische Physik & Dynamische Systeme, Technical University Dortmund, Germany. Seminar organizer: Ivan Veselic. Talk: “Exact L_2-small ball probabilities for finite-dimensional perturbations of Gaussian processes”
Jan 2018	Seminar “Calculus of Variations and applications”, Ludwig-Maximilians Universit at Munich, Germany. Seminar organizer: Rupert Frank. Talk: “Exact L_2-small ball probabilities for finite-dimensional perturbations of Gaussian processes”
Jan 2018	Postgraduate seminar in probability, department of mathematics, Technical University of Munich, Germany. Seminar organizer: Nina Gantert. Talk: “Exact L_2-small ball probabilities for finite-dimensional perturbations of Gaussian processes”
Nov 2017	Seminar of the Department of Probability Theory, Faculty of Mechanics and Mathematics, Moscow State University. Seminar organizer: Albert Shiryaev. Talk: “Exact asymptotics of small deviations in L_2-norm for finite-dimensional perturbations of Gaussian processes: a spectral approach”
Oct 2017	St. Petersburg Seminar on Probability Theory and Mathematical Statistics, Russia. Seminar organizer: Il’dar Ibragimov. Talk: “Exact asymptotics of small deviations in L_2-norm for finite-dimensional perturbations of Gaussian processes”
Dec 2015	Seminar ”Operator Models in Mathematical Physics”, laboratory of operator models and spectral analysis, Faculty of Mechanics and Mathematics, Moscow State University. Seminar organizer: Andrey Shkalikov. Talk: “Asymptotic behavior of eigenvalues for some integro-differential operators”

7.3 Short-term visits

– University Duisburg-Essen, Germany, November 2022

– Technical University of Munchen, Germany, January-February 2018

– Facultad de Ciencias, Universidad de Valladolid, Spain. November 2015

8 Participation in high-school Olympiads

As teacher / organizer

Jan 2017	Russian Winter multidisciplinary camp "Formula of Unity", organized by the Euler Foundation in cooperation with St. Petersburg State University. Teaching problem solving classes in Olympiad Mathematics. Priozersky district of the Leningrad region, Russia.
July 2016	Russian Summer multidisciplinary camp "Formula of Unity". Teaching problem solving classes in Olympiad Mathematics. Priozersky district of the Leningrad region, Russia.
July 2016	International Summer multidisciplinary camp "Formula of Unity". Teaching problem solving classes in Olympiad Mathematics. Priozersky district of the Leningrad region, Russia.
Nov 2015	Autumn camp "Formula of Unity". Teaching problem solving classes in Olympiad Mathematics & one of the leaders of the delegation from St. Petersburg. Kondopoga, Karelia, Russia.
July 2015	International Summer multidisciplinary camp "Formula of Unity". Teaching problem solving classes in Olympiad Mathematics. Priozersky district of the Leningrad region, Russia.
July 2014	The third international Summer multidisciplinary camp "Formula of Unity", organized by the Euler Foundation in cooperation with St. Petersburg State University. Problem solving classes in Olympiad Mathematics. Priozersky district of the Leningrad region, Russia.
July 2014	Summer Mathematical Camp in Sevilla, Spain. Instituto de Matemáticas de la Universidad de Sevilla (IMUS), the Sociedad Andaluza de Educación Matemática (SAEM) Thales. Leader of the Russian delegation.
July 2013	The second Summer international multidisciplinary camp "Formula of Unity", organized by the Euler Foundation in cooperation with St. Petersburg State University. Problem solving classes in Olympiad Mathematics. Priozersky district of the Leningrad region, Russia.
2014–2017	Teacher of online classes of Olympiad Mathematics ("Russian Olympiad Circles") for high-school children (12-17 years old) from non-capital regions of Russia. Part of socio-educational program "Formulo de Integreco" ("Formula of Unity")

As participant

2008	Second place in the Republic Olympiad in Mathematics Republic of Komi, Russia.
2008	Winner of the Town Olympiad in Mathematics & Physics Ukhta, Republic of Komi, Russia.
2007	Winner of the Town Olympiad in Mathematics, Physics, Chemistry. Second place in Olympiads in Informatics and English Ukhta, Republic of Komi, Russia.
2006	Winner of the Town Olympiad in Mathematics & Physics Ukhta, Republic of Komi, Russia.