Serguei Nechaev – 2017

Last Name:	NECHAEV
First name:	Serguei
Birth date:	July 9, 1962
Place of birth:	Moscow, Russia
Family status:	Married, 2 children
Position:	DR1, CNRS
Permanent affiliation:	UMR 8626, CNRS—Universite Paris XI, LPTMS, Bat.100, Universite Paris Sud, 91405 Orsay Cedex, France
Tel:	+33 7 86 55 61 34 (mob.)
e-mails:	nechaev@lptms.u-psud.fr sergei.nechaev@gmail.com

Education

1985: Graduated from the Physical Department of the Moscow State University. Master work in the statistical physics of polymers.

1989: Ph.D. in Physics from the Physical Department of the Moscow State University; subject of Ph.D: "Topological Constraints in the Statistical Physics of Macromolecules".

1996: Doctoral Degree (Dr.Sci.D.) in Physics from the Landau Institute for Theoretical Physics; subject of Dr.Sci.D.: "Statistics of Knots and Entangled Random Walks".

Permanent employment

1985 – 1991: Stageur, Researcher at the Institute of Chemical Physics (Russian Academy of Sciences).

1991 – 2007: Researcher, Senior researcher (since 1996) at the Landau Institute for Theoretical Physics (Russian Academy of Sciences).

1998 – 2008: Charge de Recherche (CR1) at CNRS-Universite Paris XI, lab. LPTMS

Since 2007: Leading researcher at the Lebedev Physical Institute (Russian Academy of Sciences).

2008 – 2017: Directeur de Recherche (DR2) at CNRS-Universite Paris XI, lab. LPTMS

Since 2017: Directeur de Recherche (DR1)

2015 – till now: Director of the Interdisciplinary Scientific Center Poncelet (CNRS, UMI 2615) at the Independent University (Moscow, Russian Federation)

Pedagogical activity

1990 – 1992:	Supervisor of S. Izrailev (Master Degree in Physics, graduated from Institute of Physics and Technology, Russia)
1998 – 2000:	Supervisor of R. Bikbov (Master Degree in Physics, Ph.D., graduated from Institute of Physics and Technology, Russia)
1999 – 2001:	Supervisor of A. Naidenov (Bachelor Degree in Physics, Master Degree in Physics, Institute of Physics and Technology, Russia)
1999 – 2002:	Supervisor of R. Voituriez (Ph.D., graduated from ENS, Paris)
2004 – 2006:	Supervisor of Ph.D. student G. Sitnikov (graduated from Institute of Physics and Technology, Russia)
2007 – 2008:	Supervisor of M. Tamm for his postdoc position at LPTMS
2010 – 2013:	Supervisor of PhD student Olga Valba graduated from the Institute of Physics and Technology (Russia)
2011 – 2012:	Organizer of the young researcher's seminar on the theory of complex systems and its application in biophysics, Independent University (Moscow)
2012 – 2013:	Supervisor of Nils Haug (graduated from Berlin University) for his Master work
2014:	Organizer of the young researcher's seminar "Mathematical methods in the theory of disordered media", Higher School of Economics, (Moscow)
2014 – 2015:	Co-supervisor of Ph.D. student Andrey Lokhov (graduated from Ecole Polytechnique)
2015:	Lecture course at the Higher School of Economics and Moscow Independent University "Geometry in the theory of random walks" (April-May, 2015)
2015:	Lecture course at the SERC School on Topology and Condensed Matter Physics (organized in 2015 by RKM Vivekananda University at S.N Bose National Center for Basic Sciences, Calcutta, India)
2016 – 2017:	Supervisor of V. Kovaleva (Master degree in Physics from the Institute of Physics and Technology, Russia)
2016 – 2019:	Co-supervisor of K. Polovnikov (PhD in Physics, graduated from the Moscow State University, Russia)
2013:	Public lecture "Topology of ropes, knots and fractal DNA folding in chromosomes"
	http://polit.ru/article/2013/05/31/nechaev/
	https://www.youtube.com/watch?v=XHyyq6L_Y2w
2013:	Constructors of molecular machines
	http://www.ng.ru/science/2013-09-11/9_constructors.html
2016:	Public lecture "On non-Euclidean geometry in nature"
	https://postnauka.ru/video/56827

2017: Public lecture “Mathematical Walks: Sergei Nechaev”

http://www.skoltech.ru/mathwalks/en/

2017: Public lecture “Collective effects in topology”

https://www.youtube.com/watch?v=yw48YWnfuUk&t=5s

2017: Public lecture “Mathematics and biology of big data”

https://www.youtube.com/watch?v=51Jbehan4mk&t=2283s

2017: Organizer of memorial scientific session of the Russian Academy of Sciences devoted to the 100-anniversary of I.M. Lifshitz http://ufn.ru/ru/events/lifshits_im100.html

Video of lecture of S. Nechaev “Rare event statistics and hierarchy: from Lifshitz tails to modular invariance”

https://www.youtube.com/watch?v=miWm-N52aBY&list=PLqBQUrkSOgkLkx5ekpZz0gmSCSbv2oYlg&index=2

Organizational Activity

2003: Organizer of the trimester at IHP (Institut Henri Poincare) "Geometry and Statistics of Random Growth"

2003 – 2004: CNRS mission (1 year) to the Poncelet Laboratory at the Independent University (Moscow, Russia)

2004: Organizer of the conference "Geometry and Combinatorics in Physics" (Independent University, Moscow)

2005: Organizer of the conference "Combinatorial Methods in Physics and Knot Theory" (Independent University, Moscow)

2006: Organizer of the conference "Structure formation and random processes on graphs and networks" (LPTMS, Orsay)

2009 – 2010: CNRS mission (1 year) to the Poncelet Laboratory at the Independent University (Moscow, Russia)

2011: Organizer of the International workshop at Lorentz Center (Leiden) on Extreme Value Statistics of Correlated Random Variables

2014: Organizer of the international colloquium "Topological Interactions" – satellite of the symposium "Condensed matter in Paris-2014"

2014: Organizer of the international workshop "Random geometry in physics" (Steklov Institute, Moscow, Russia)

Since 2015: Director of the Poncelet Laboratory, which is going to be reformatted into the Interdisciplinary Scientific Center of Physics, Mathematics and Informatics.

2016: Organizer of the Round table “Big data in biology” (Moscow Institute of Physics and Technology, Russia)

2016: Organizer of the Conference “Critical and collective effects in graphs and networks” (Moscow Institute of Physics and Technology, Russia)

2017:	Organizer of the Conference “Critical and collective effects in graphs and networks-2” (Moscow Independent University, Russia)
2017:	Organizer of the workshop “Quantum information and topological recursion” (Skoltech, Moscow)
2017:	Organizer of the conference “Theory and Modeling of Complex Systems in Life Sciences” (Saint Petersburg, Russia)

Administration

2015-till now:	Director of the Poncelet Laboratory, which has been reformatted in 2017 into the **Interdisciplinary Scientific Center of Physics, Mathematics and Informatics (ISCP UMI 2615)** http://www.poncelet.ru/ Also see the information here: http://www.cnrs.fr/inp/spip.php?article5281 https://ru.ambafrance.org/Sreation-du-Centre-scientifique-interdisciplinaire-Poncelet-franco-russe

Grants

2005 – 2007:	Coordinator of the project "Neuds et tresses" (Nouvelles Interfaces des Mathematiques) ACI-NIM-2004-243
2010 – 2012:	Leader of the French team of the international project (England – Spain – Netherlands – France) "GRAPPLE" (Iterative modelling of gene regulatory interactions underlying stress, disease and ageing). French part is guided by ANR-09-SYSB-004.
2011 – 2013:	"WALKMAT" ANR grant 2011-BS04-013-01
2012 – 2013:	LABEX-PALM grant "Pro-Net" AO-2012-1
2013 – 2014:	Leader (French side) of the MIT–France Seed Fund "Genome in 3D: Fractal and Topological Properties of DNA Folding" (MIT-Orsay University)
2014 – 2017:	Responsible for the French part of IRSES International project (UK-France-Russia)
2016 – 2018:	Grant of the Russian Foundation for Basic Research (RFBR) “Invariants of knots and nonperturbative effects in statistical physics and gauge theories”, No. 16-02-00252

Participation in International Conferences (invited talks and lectures since 2007)

2007:	"Interfaces between Physics and Computer Science" (Bremen, 2007)
2007:	"Statistical mechanics of distributed information systems" (Mariehamn, 2007)

2009:	"Random functions and random surfaces" (Montreal, Canada, 2009)
2009:	Dobrushin International Conference (Moscow, Russia, 2009)
2009:	Fifth International Conference "Solitons, Collapses and Turbulence" (Chernogolovka, Russia, 2009)
2010:	Stochastic processes in physics and biology (Moscow, Russia, 2010)
2010:	Second International Workshop on Soft Matter and Biological Systems (Fez, Morocco, 2010)
2010:	Optimization and optimal transport (St. Petersburg, 2010)
2010:	Royal Society meeting "Knots and statistical physics" (Kavli Royal Society Center, England, 2010)
2010:	NORDITA meeting on extreme value statistics (Stockholm, 2010)
2011:	Optimization and stochastic methods for spatially distributed information (St. Peterbourg, Russia, 2011)
2011:	Geometric Topology of Knots (Piza, Italy, 2011)
2011:	Random Processes, Conformal Field Theory and Integrable Systems (Poncelet Laboratory, Moscow, 2011)
2011:	16th Itzykson Meeting on Extremes and Records (Saclay, France, 2011)
2011:	88e Rencontre entre physiciens theoriciens et mathematiciens: Discretisation en mathematiques et en physique (IRMA, Strasbourg, France, 2011)
2012:	Geometry and Topology (Independent University, Moscow)
2013:	Informational Technologies and Systems-2013 (Kaliningrad, Russia)
2014:	Kargin symposium "Polymers|2014" (Moscow, Russua)
2014:	Symposium of the German Physical Society (Dresden, Germany)
2014:	International conference "Mobility and Order in Polymer Systems" (St. Petersburg, Russua)
2014:	International conference on statistical physics, "SigmaPhi-2014" (Rhodes, Grece)
2014:	International workshop "Random geometry in physics" (Steklov Institute, Moscow, Russia)
2015:	Conference on Complex systems (Karabakh, Armenia)
2015:	International conference "p-adic Mathematical Physics and its Applications" (Belgrade, Serbia)
2015:	Lectures at the SERC School on "Topology and Condensed matter physics" (Calcutta, India)
2016:	International conference “String theory, integrable models and representation theory” (Independent University, Moscow)
2016:	International conference “Ising lectures-2016” (Lvov, Ukraine)
2016:	International conference “Genome in space and time” (Trieste, Italy)

2016:	Conference “Informational technologies and systems-2016” (St. Petersburg, Russia)
2017:	Memorial session of the Russian Academy of Sciences “I.M. Lifshitz – 100” (Moscow, Russia)
2017:	Conference “Critical and collective effects in graphs and networks-2” (Moscow, Russia)
2017:	Skoltech-MIT Conference: "Shaping the Future: Big Data, Biomedicine and Frontier Technologies” (Skoltech, Moscow)
2017:	Workshop “Quantum information and topological recursion” (Skoltech, Moscow)
2017:	Conference “Theory and Modeling of Complex Systems in Life Sciences” (Saint Petersburg, Russia)
2017:	Conference “Integrability and Chaos in Multicomponent Systems” (Nordita, Vladivostok, Russia)

Awards

1986:	The Gold Medal of the USSR Ministry of Educations in the All-Union competition in mathematics among postgraduate students.

Publications

Total number of publications:	115	
Books:	1	"Statistics of Knots and Entangled Random Walks" (World Sci. Publ., 1996)
Chapters in special proceedings:	5	
Number of popular papers:	2	

Key results during the career

I. On non-Euclidean geometry and knot topology

1. In 1985-1988 we have investigated the statistics of unentangled random walks in regular lattices of topological obstacles and have shown its fundamental relation to the diffusion in the non-Euclidean geometry [2, 4, 9].

2. In 1988 we have theoretically predicted the new condensed state of an unentangled and unknotted macromolecule in a poor solvent. We have named this state “the crumpled globule” and have studied its unusual fractal properties. In 2009, the team of US authors has reported the existence of the new structural organization of a DNA chain in a human genome in a form of a “crumpled (fractal) globule” [6, 7].

3. In 1991 we have investigated the statistics of conditional distribution of matrix-valued “Brownian bridges” [16, 17]. We have shown that the Lyapunov exponent of the subproduct of random *SL*(2,R)-matrices grows sublinear under the condition that the whole chain of random matrices is equal to unit matrix. This work met great attention in the works of P. Bougerol, A. Vershik, and has created the mathematical background for studying statistical properties of topological complexity of conditional distribution in ensembles of random knots and braids.

4. In 2000-2004 we have investigated the “topological correlations” in unknotted polymer chains in collapsed (globular) phase using methods of algebraic topology, and have shown that the typical equilibrium trajectory of collapsed (i.e. globular) unknotted chain has space-filling structure: the chain densely fills the volume on all scales, remaining almost unknotted on each scale [51, 54, 59, 60].

The breakthrough in the interest to the crumpled globule happen after the experimental work of the MIT-Harvard team in 2009. Immediately after, the concept of crumpled (fractal) globule became the candidate for the new paradigm explaining many realistic features the DNA packing and functioning in a human genome.

Our works constitute the basis of the “Statistical (or probabilistic) topology of polymers". The conceptual steps of creation this new branch lying at the edge of statistical physics, topology and macromolecular physics, are reviewed in lecture notes S.K. Nechaev, “Concepts of polymer statistical topology”, [107].

II. On growth of random heaps ("Tetris" game), matching problems, and vicious walks

During 1996-2006 we worked on statistical properties of braids and proposed (together with A.M. Vershik) the concept of “*locally free group*”, which enabled us to give the best known upper and lower estimations for the word counting problem in a braid group B_n. During that time, we found that statistics of growth can be presented by sequential random ballistic deposition like “tetris” game with special commutation relation for blocks added to nearest neighboring columns.

1. Using the “tetris” point of view, we were have theoretically solved few problems on statistics of directed entangled strings [31, 36, 37, 38, 45]. In particular, we proposed microscopic consideration of topological relaxation of entangled flux lines [49].

2. We have theoretically derived (together with S. Majumdar) exact asymptotic results for the distribution of the longest common subsequence (LCS) of a pair of random sequences [58, 63, 71] from the point of view of "random deposition" process.

3. We have proposed to consider the new class of random matrices - the "randomized Parisi matrices" [74, 75, 76]. We have investigated the spectral properties of these matrices and discussed their application for description of scale-free networks. Currently (in 2013-2015) it has been recognized [97] that these matrices can be successfully used to describe fine structure of DNAs in chromosomes folded as "fractal globules".

4. Since 2012 we are interested in the bunch of problems lying at the edge of statistics of "vicious" random walks, exactly solvable models, integrable systems and algebraic knot theory. In particular, we have considered the following problems:

a) Sequential ballistic deposition (BD) with next-nearest-neighbor (NNN) interactions in the N-column box is viewed as a time-ordered product of $N x N$-matrices consisting of a single sl_2-block which has a random position along the diagonal. We relate the uniform BD growth with the diffusion in the symmetric space H_N. In particular, the distribution of the maximal height of a growing heap is connected with the distribution of the maximal distance for the diffusion process in H_N. The coordinates of H_N are interpreted as the coordinates of particles of the one-dimensional Toda chain [82].

b) Given a spanning forest on a large square lattice, we consider by combinatorial methods (by the Kirchhoff theorem) a correlation function of *k* paths (for odd *k*) along branches of trees or, equivalently, *k* loop-erased random walks. Starting and ending points of the paths are grouped in a fashion a k-leg watermelon. Investigating the spanning forest stretched along the meridian of this watermelon, we have shown that the two-dimensional *k*-leg loop-erased watermelon reunion exponent is converting into the scaling exponent for the reunion probability (at a given point) of *k* (1+1)-dimensional vicious walkers. By this we have proposed the model, in which by changing the stretching of loop-erased walks, we can pass from the conformal field theory with the central charge $c = -2$ (no stretching) to the random matrix theory (full stretching) [86].

III. On phase transitions in RNA matching

Since 2012 we are pushing forward the works on statistical analysis of systems with complex RNA-like architecture. Few new results have been obtained during 2012-2015. For example, we have investigated the fraction *f* of nucleotides involved in the formation of a cactus like secondary structure of random heteropolymer RNA-like molecules. In the low temperature limit, we study this fraction as a function of the number *c* of different nucleotide species. We show, that with changing *c*, the secondary structures of random RNAs undergo a morphological transition: $f(c) \to 1$ for $c > c_{cr}$ as the chain length n goes to infinity, signalling the formation of a virtually "perfect" gapless secondary structure; while $f(c) < 1$ for $c > c_{cr}$, what means that a non-perfect structure with gaps is formed. The strict upper and lower bounds $2 < c_{cr} < 4$ are proven, and currently the "topological perturbation theory" is proposed to estimate the value of c_{cr} analytically. We discussed the relevance of the transition from the evolutional point of view and claimed that our statistical finding rhymes with the hypothesis of the “RNA world” [81, 88, 95].

IV. On DNA crumpling and molecular machines

Being the “parents” of the concept of “crumpled” globular structure (proposed in 1988) which became crucial for collapsed DNA in chromatin, after a verification of this hypothesis in Hi-C experiments (Harvard and MIT), we have continued (since 2014) working in this direction. In particular, we made the following contribution to this subject:

1. The statistical properties of intra-chromosome maps obtained by a genome-wide chromosome conformation capture method (Hi-C) we have described in the framework of

the hierarchical crumpling (HC) model of heteropolymer chain with quenched disorder in the primary sequence. The model captures basic features of Hi-C maps [97]: (i) The 1/*s*–decay of the averaged signal intensity on the distance s away from the main diagonal of the map, (ii) the chess-board-like intermittency of lighter and darker regions, (iii) the hierarchical block-diagonal structure. It is conjectured that the manifestation of hierarchical structure is the signature of the uniqueness of DNA similar to the role of "replica overlap" in statistics of disordered systems.

2. Recently we have undertaken the massive numeric simulation of the unknotted collapsed polymer ring and have explicitly demonstrated the evident signature of the fractal globule structure [98].

3. We are continuing working on the experimental implementation of the "molecular machine" built on the principles of the fractal globule folding. The statistical and dynamic analysis of corresponding elastic networks demonstrates the principal possibility to create artificial molecular machine and conjecture about its role in prebiological evolution [90, 94, 96].

V. On geometry of buckling

In 2000 we (together with R. Voituriez) were the first who have proposed the conformal approach for the description of isometric embedding of exponentially growing tissues in the Euclidean three-dimensional space [52]. We have entitled this problem “jupe à godets”. Since the subject is still very active, in 2016 we have reconsidered this problem in more detail and have studied the optimal embedding in the three-dimensional space of exponentially growing squeezed surfaces, like plants leaves, or 2D colonies of exponentially reproducing cells. We have shown, that the boundary profile of a growing tissue is described by the 2D eikonal equation, which provides the geometric optic approximation for the wave front propagating in the media with inhomogeneous refraction coefficient. The variety of optimal surfaces embedded in 3D is controlled by the spatial dependence of the refraction coefficient which, in turn, is dictated by the local growth protocol [105].

VI. On critical and collective phenomena in evolutionary networks

During 2015-2017, we have published a series of works on critical and collective behavior in constrained random networks [91,103, 106, 110, 112].

1. We considered the canonical ensemble of *N*-vertex Erdos-Renyi (ER) random topological graphs with quenched vertex degree, and with fugacity μ for each closed triple of bonds. We claimed complete defragmentation of large-*N* graphs into the collection of 1/*p* almost full subgraphs (cliques) above critical fugacity, μ_c, where *p* is the ER bond formation probability. Evolution of the spectral density, $\rho(\lambda)$, of the adjacency matrix with increasing μ leads to the formation of a multi-zonal support. Eigenvalue tunneling from the central zone to the side one means formation of a new clique in the defragmentation process. The adjacency matrix of the network ground state has a block-diagonal form, where the number of vertices in blocks fluctuate around the mean value *Np*. The spectral density of the whole network in this regime has triangular shape. We interpret the phenomena from the viewpoint of the conventional random matrix model and speculate about possible physical applications [91, 106, 110].

2. We have considered critical behavior in the ensemble of polychromatic Erdos-Renyi networks (CERN) and regular random graphs (RRG), where network vertices are painted in different colors. The links can be randomly removed and added to the network subject to the condition of the vertex degree conservation. In these constrained graphs we run the Metropolis procedure, which favorites the connected unicolor triads of nodes. Changing the chemical potential, μ, of such triads, for some wide region of μ, we find the formation of a finite plateau in the number of inter-color links, which exactly matches the finite plateau in the network algebraic connectivity (the value of the first non-vanishing eigenvalue of the Laplacian matrix, λ_2). We claim that at the plateau the spontaneously broken Z_2-symmetry is restored by the mechanism of modes collectivization in clusters of different colors. The phenomena of a finite plateau formation holds also for polychromatic networks with M =2,3,… colors. The behavior of polychromatic networks is analysed via the spectral properties of their adjacency and Laplacian matrices [103, 112].

VII. On number-theoretic properties of sparse random matrices

During 2015-2016 we paid attention to the investigation of the eigenvalue density in ensembles of large sparse Bernoulli random matrices. We have demonstrated that the fraction of linear subgraphs just below the percolation threshold is about 95% of all finite subgraphs, and the distribution of linear chains is purely exponential. We have analyzed in detail the spectral density of ensembles of linear subgraphs, discussed its ultrametric nature and show that near the spectrum boundary, the tail of the spectral density exhibits a Lifshitz singularity typical for Anderson localization [102].

Recently, we have discussed the number-theoretic properties of distributions appearing in physical systems when an observable is a quotient of two independent exponentially weighted integers. The spectral density of ensemble of linear chains (graphs) weighted exponentially $\sim f^{L}$ ($0 < f < 1$), where L is the chain length, serves as a particular example. At $f \to 1$, the spectral density can be expressed through the discontinuous at all rational points, the so-called Thomae (or the "raindrop") function. We have suggested a continuous approximation of the raindrop function, based on the Dedekind eta-function near the real axis. We have provided simple arguments, based on the "Euclid orchard" construction, that demonstrate the presence of Lifshitz tails, typical for the 1D Anderson localization, at spectral edges. We have also paid attention to the connection of the Dedekind eta-function near the real axis to the phyllotaxis and invariant measures of some continued fractions studied by Borwein and Borwein in 1993 [111].

VIII. Current activity

A. On fractal Brownian motion

In 2017 we have started the analytic investigation of fractal structure of collapsed polymer chains in the framework of the "β-model" proposed by A. Amitai and D. Holcman. We have analyzed the statistical properties of a polymer chain with pairwise quadratic interactions and algebraically decreasing elastic constants, $A_s \sim s^{-\gamma}$, where s is the chemical distance between monomers and $\gamma \in [2,4]$. We have shown that the resulting conformation is Gaussian and self-similar with the fractal dimension, controlled by γ. Using path integrals, we establish the connection between the quadratic action of a particle with memory-dependent kernel and the partition function of a Gaussian polymer with pairwise interactions. Now we plan to develop a theory of coil-fractal globule phase transition [114].

B. On critical phenomena in knot theory with relation to integrable systems and vicious walks

1. We consider the critical behavior of some physical systems in context of their relations with vicious walkers and generalize in different directions previous observation concerning the relation between reunion probability on a circle and the partition function of 2D YM on S_2. We argue that there is a third order phase transition at some critical value of the initial and final distributions for the random walkers. The role of the topological q-term in the vicious walkers setup is clarified. We also discuss the relation of the vicious walkers problem with few counting problems in 4D SUSY theories: the black hole partition function for the mixed ensemble and the superconformal index. The critical behavior for the random walks involving the area fugacity is analyzed in context of knot superpolynomials [100].

2. Currently we are trying to understand the origin of the connection between knot statistics, some aspects of theory of integrable systems and edge scaling of random matrix ensembles. Specifically, we consider the relation between three physical problems: 2D directed lattice random walks with fixed area under the curve, ensembles of $T_{n,n+1}$ torus knots, and instanton ensembles in 5D SQED having one compact dimension in Ω background with 5D Chern-Simons term at the level one. All these ensembles exhibit the critical behavior typical for the "area+length+corners" statistics of grand ensembles of 2D directed paths [104].

C. On phase transitions and path counting on graphs

1. We study the asymptotic behavior of the number of paths of length *N* on several classes of infinite graphs with a single special vertex. This vertex can work as an entropic trap for the path, i.e. under certain conditions the dominant part of long paths become localized in the vicinity of the special point instead of spreading to infinity. We study the conditions for such localization on decorated star graphs, regular trees and regular hyperbolic graphs as a function of the functionality of the special vertex. In all cases the localization occurs for large enough functionality. The particular value of transition point depends on the large-scale topology of the graph. The emergence of localization is supported by the analysis of the spectra of the adjacency matrices of corresponding finite graphs [109].

2. In 2017 we started the investigation of the eigenvalue statistics of exponentially weighted ensembles of full binary trees and *p*-branching star graphs. We have shown that spectral densities of corresponding adjacency matrices demonstrate peculiar ultrametric structure inherent to sparse systems. In particular, the tails of the distribution for binary trees share the "Lifshitz singularity" emerging in the one-dimensional localization. The hierarchical structure of spectra of adjacency matrices can be interpreted as sets of resonance frequencies, that emerge in ensembles of fully branched tree-like systems, known as dendrimers. However, the spectrum is not determined by the specific cluster topology, but has rather the number-theoretic origin, reflecting the peculiarities of the rare-event statistics typical for one-dimensional systems with a quenched structural disorder. The similarity of spectral densities of an individual dendrimer and of ensemble of linear chains with exponential distribution in lengths, demonstrates that dendrimers could be served as simple disorder-less toy models of one-dimensional systems with quenched disorder [108].

List of publications

[1] S.K. Nechaev, A.N. Semenov, A.R. Khokhlov, Orientational ordering in solutions of polymer chains with rotational mechanism of exibility, Vysokomolek. Soed. (A), 25 (1983), 1063-1070 (in Russian).

[2] A.R. Khokhlov, S.K. Nechaev, Polymer chain in an array of obstacles, Phys. Lett. (A), 112 (1985), 156-160.

[3] S.K. Nechaev, A.R. Khokhlov, High-elasticity of chains with topological constraints, Vysokomolek. Soed. (B), 29, (1987), 533-536 (in Russian).

[4] S.K. Nechaev, A.N. Semenov, M.K. Koleva, Dynamics of polymer chain in an array of obstacles, Physica (A), 140 (1987), 506-520.

[5] S.K. Nechaev, A.R. Khokhlov, Polymer chain elasticity in the presence of topological obstacle, Physics Letters (A), 126 (1988), 431-433.

[6] A.Yu. Grosberg, S.K. Nechaev, E.I. Shakhnovich, The infuence of topology on homopolymer collapse and on biopolymer self-organisation, Biofizika (in Russian), 33 (1988), 247-253.

[7] A.Yu. Grosberg, S.K. Nechaev, E.I. Shakhnovich, The role of topological constraints in the kinetics of collapse of macromolecules, J. de Physique, 49 (1988), 2095-2100.

[8] A.Yu. Grosberg, S.K. Nechaev, E.I. Shakhnovich, Collapse Transition in Homopolymers: A Kinetic Study. Biofizika (in Russian), 38 (1988), 731-739

[9] S.K. Nechaev, Topological properties of a 2D-polymer chain in the lattice of obstacles, J. Phys. (A): Math. Gen., 21 (1988), 3659-3671.

[10] S.K. Nechaev, Statistics of 3D-dynamically rebuilt trees near the uncrossible wall, Europhys. Lett., 10 (1989), 317-322.

[11] A.Yu. Grosberg, D.V. Kuznetsov, S.K. Nechaev, Static and dynamic structures of polymers and their possible applications in biocybernetics, Studia Biophysica, 132 (1989), 25-34.

[12] S.K. Nechaev, A.R. Khokhlov, Ring and linear chains near the gel surface, Vysokomolek. Soed. (in Russian), 31-B (1990), 705-708.

[13] Ya.I. Kogan, S.K. Nechaev, D.V. Khveshchenko, Vortices in the 2D-nematic, Zh. Eksp. Teor. Fiz. (in Russian), 98 (1990), 1505-1511.

[14] S.K. Nechaev, Overview of polymer topology, Int. J. Mod. Phys. (B), 4-B (1990), 1809-1847

[15] D.V. Khveshchenko, Ya.I. Kogan, S.K. Nechaev, Vortices in the lattice model of planar nematic, Int. J. Mod. Phys. (B), 4 (1991), 647-659.

[16] S.K. Nechaev, Ya.G. Sinai, Limiting-type theorem for conditional distributions of products of independent unimodular 2x2 matrices, Bol. Soc. Bras. Mat., 21 (1991), 121-132.

[17] L.B. Koralov, S.K. Nechaev, Ya.G. Sinai, Limiting probability distribution for a random walk with topological constraints, Chaos, 1 (1991), 131-134.

[18] A.Yu. Grosberg, S.K. Nechaev, Topological constraints in strong gel collapse, Macromolecules, 24 (1991), 2789-2793.

[19] A.Yu. Grosberg, S.K. Nechaev, Algebraic invariants of knots and disordered Potts model, J. Phys. (A): Math.Gen., 25 (1992), 4659-4672.

[20] A.Yu. Grosberg, S.K. Nechaev, Averaged Kauffmann invariant and quasiknot concept for linear polymers, Europhys. Lett., 20 (1992), 613-619.

[21] S.K. Nechaev, Ya.G. Sinai, Limiting behavior of 2D random walks with topological constraints, Teorija Verojatnostej i ee primenenija, (in Russian) (Prob. Theor. Appl.), 1993, 38 (1993), 331-344.

[22] S.K. Nechaev, V.G. Rostiashvili, Polymer chain in a random array of topological obstacles: I. Collapse of loops, J. de Physique II, 3 (1993), 91-104

[23] A.Yu. Grosberg, S.K. Nechaev, Polymer topology, Adv. Polym. Sci., 106, 1-30, in "Polymer Characteristics", (Springer, 1993)

[24] S.K. Nechaev, A.Yu. Grosberg, Entropy of knots and statistics of random walks, in Proceedings of the conference "Soft Order in Physical Systems", Les Houches (France), 1993, published by Plenum Press.

[25] V.G. Rostiashvili, S.K. Nechaev, T.A. Vilgis, Polymer chain in a random array of topological obstacles: II. Classification of complex loops, Phys. Rev. E 48 (1993) 33143320

[26] A.Yu. Grosberg, S.F. Izrailev, S.K. Nechaev, Phase transition in a heteropolymer chain at a selective interface, Phys. Rev. (E), 50 (1994), 1912-1921

[27] S.K. Nechaev, A.M. Vershik, Random walks on multiconnected manifolds and conformal field theory, J. Phys. (A): Math. Gen., 27 (1994), 2289-2298

[28] S.K. Nechaev, Nematic phase transition in entangled directed polymers, Pis'ma v ZhETF (in Russian), 60 (1994), 277-284 (JETP Letters)

[29] S. Nechaev, Y.-C. Zhang, Exact solution of 2D Wetting Problem in Periodic Potential, Phys. Rev. Lett., 74 (1995), 1815-1819

[30] A. Khokhlov, S. Nechaev, Topologically Driven Compatibility Enhancement in the Mixtures of Rings and Linear Chains, J. de Physique, II, 6 (1996), 1547-1555

[31] S. Nechaev, A. Grosberg, A. Vershik, Random walks on braid groups: Brownian bridges, complexity and statistics. J. Phys. (A): Math. Gen., 29 (1996), 2411-2434

[32] V. Tchijov, S. Nechaev, S. Rodriquez-Romo, Interface structure in colored DLA model, Pis'ma v ZhETF (in Russian), 64 (1996), 549-553 (JETP Letters)

[33] S.K. Nechaev, A.Yu. Grosberg, Topologcal problems in statistical physics of polymers, in "Mathematical methods in contemporary chemistry", (Gordon & Breach, 1996)

[34] S.K. Nechaev, Statistics of Knots and Entangled Random Walks, (WSPC: Singapore, 1996) - book

[35] M. Monastyrsky, S. Nechaev, Correlation functions for some conformal theories on Riemann surfaces, Mod. Phys. Lett. (A) 12 (1997), 589-596

[36] J. Desbois, S. Nechaev, Statistical Mechanics of Braided Markov Chains: I. Analytic Methods and Numerical Simulations J. Stat. Phys., 88 (1997), 201-223

[37] J. Desbois, S. Nechaev, Statistics of reduced words in locally free and braid groups: Abstract studies and applications to ballistic growth model, J. Phys. (A): Math. Gen., 31 (1998), 2767-2784

[38] A. Comtet, S. Nechaev, Random operator approach for word enumeration in braid groups, J. Phys. (A): Math. Gen., 31 (1998), 5609;

[39] S. Nechaev, Localization in a simple multichain catalytic absorption model, J. Phys. (A): Math. Gen, 31 (1998), 1965-1980

[40] G. Oshanin, S. Nechaev, A. M. Cazabat, M. Moreau, Kinetics of anchoring of polymer chains on substrates with chemically active sites, Phys. Rev. (E), 58 (1998), 6134

[41] S. Nechaev, Problems of probabilistic topology: Statistics of knots and noncommutative random walks, UFN (Sov. Phys. Uspekhi), 168 (1998), 369

[42] S. Nechaev, Statistics of knots and entangled random walks, Lectures presented at Les Houches 1998 Summer School "Topological Aspects of Low Dimensional Systems", July 7-31, 1998 (NATO Advanced Study Institute, session LXIX: EDP Sciences; Springer, 1999)

[43] S. Nechaev, G. Oshanin, A. Blumen, Anchoring of polymers by traps randomly placed on a line, J. Stat. Phys., 98 (2000), 281-303

[44] S. Nechaev, Polymers, ropes, knots and non-Euclidean geometry, Kvant, No.3 (2000) (in Russian)

[45] A.M. Vershik, S. Nechaev, R. Bikbov, Statistical properties of locally free groups with application to braid groups and growth of heaps, Comm. Math. Phys., 212 (2000), 469-501

[46] R. Bikbov, S. Nechaev, On the limiting power of set of knots generated by 1+1- and 2+1- braids, J. Math. Phys., 40 (1999), 6598-6608

[47] R. Voituriez, S. Nechaev, Multifractality of entangled random walks and non-uniform hyperbolic spaces, J. Phys. (A): Math. Gen., 33 (2000), 5631-5652

[48] A. Comtet, S. Nechaev, R. Voituriez, Multifractality in uniform hyperbolic lattices and in quasi-classical Liouville field theory, J. Stat. Phys., 102 (2001), 203

[49] R. Bikbov, S. Nechaev, Topological relaxation of entangled flux lattices: Single vs collective line dynamics, Phys. Rev. Lett., 87 (2001) 150602

[50] A. Naidenov, S. Nechaev, Adsorption of a random heteropolymer at a potential well revisited: location of transition point and design of sequences, J.Phys. (A): Math. Gen., 34 (2001) 5625-5634

[51] O. Vasilyev, S. Nechaev, Thermodynamics and topology of disordered systems: Statistics of random knot diagrams on finite lattices, JETP, 93 (2001) 1119

[52] S. Nechaev, R. Voituriez, On the plants leaves boundary, "jupe a godets" and conformal embeddings, J.Phys. (A): Math. Gen. 34 (2001) 11069-11082

[53] S. Nechaev, A. Naidenov, On reactions of type $A + A + \ldots + A \to 0$ on 1D periodic lattice of catalytic centers, JETP Letters, 76 (2002) 61

[54] O.Vasilyev, S.Nechaev, On topological correlations in trivial knots: New arguments in support of the crumpled globule concept, Theor. Math. Phys., 134 (2003) 142-159

[55] S. Nechaev, R. Voituriez, Random walks on 3-strand braid and related hyperbolic groups, J. Phys. A: Math. Gen. 36 (2003), 43-66

[56] S.Nechaev, O.Vasilyev, Metric structure of ultrametric spaces, J.Phys.A: Math. Gen. 37 (2004) 3783-3804

[57] S. Nechaev, O. Vasilyev, On metric structure of ultrametric spaces, Proceedings of the 1st International Conference on *p*-adic Mathematical Physics, Steklov Math. Inst., Moscow, 2004

[58] S.N. Majumdar, S. Nechaev, An anisotropic ballistic deposition model with links to the Ulam problem and the Tracy-Widom distribution, Phys.Rev.E, 69 (2004) 011103

[59] S. Nechaev, O. Vasilyev, On topological correlations in trivial knots: From Brownian bridges to crumpled globules, Journal of Knot Theory and Its Ramifications, 14 (2005) 243-263

[60] S. Nechaev, O. Vasilyev, Thermodynamics and topology of disordered knots: Correlations in trivial lattice knot diagrams, in "Physical and Numerical Models in Knot Theory", chapter 22, pp. 421-472, *Series on Knots and Everything*, (WSPC: Singapore, 2005)

[61] S. Nechaev, R. Voituriez, Conformal Geometry and Invariants of 3-strand Brownian Braids, Nuclear Physics B, 714, 336-356 (2005)

[62] M. V. Tamm, S. Nechaev, I.Erukhimovich, Statistics of randomly branched polymers in a semi-space, European Physical Journal E, 17, 209-219 (2005)

[63] S.N. Majumdar, S.K. Nechaev, Exact asymptotic results for the Bernoulli matching model of sequence alignment, Phys. Rev. E 72, 020901(R) (2005)

[64] G.V. Sitnikov, S.K. Nechaev, M.D. Taran, A Quantitative Mean-Field Theory of the Hydrophobic Effect of Neutral and Charged Molecules of Arbitrary Geometry, ZhETF (JETP), 128, 1099-1116 (2005)

[65] G. Sitnikov, S. Nechaev, M. Taran, A. Muryshev, Application of a two-length scale field theory to the solvation of charged molecules: I. Hydrophobic effect revisited, J.Chem.Phys., 124, 094501 (2006)

[66] A.Y. Grosberg, S. Nechaev, M. Tamm, O. Vasilyev, How long does it take to pull an ideal polymer into a small hole? Phys. Rev. Lett. 96, 228105 (2006)

[67] M.V. Tamm, S.K. Nechaev, Necklace-cloverleaf transition in associating RNA-like diblock copolymers. Phys. Rev E, 75, 031904 (2007)

[68] F. Hivert, S.K. Nechaev, G. Oshanin, O. Vasilyev, On the distribution of surface extrema in several one- and two-dimensional random landscapes, J.Stat.Phys., 126, 243-279 (2007)

[69] G. Oshanin, R. Voituriez, S. Nechaev, O. Vasilyev, F. Hivert, Random patterns generated by random permutations of natural numbers, accepted for publication in European Physical Journal - Special Topic 143, 143-157 (2007)

[70] E. Katzav, S. Nechaev, O. Vasilyev, Longest increasing subsequence as expectation of a simple nonlinear stochastic partial differential equation with a low noise intensity, Phys. Rev. E 75, 061113 (2007)

[71] S.N. Majumdar, K. Mallick, S.K. Nechaev, Bethe Ansatz in the Bernoulli Matching Model of Random Sequence Alignment, Phys. Rev. E 77, 011110 (2008)

[72] D.M. Gangardt, S.K. Nechaev, Wetting transition on a one-dimensional disorder, J. Stat. Phys. 130, 483-502 (2008)

[73] S.K. Nechaev, M. Tamm, Unzipping of two random heteropolymers: Ground state energy distribution and finite size effects, Phys. Rev. E, 78, 011903 (2008)

[74] V.A. Avetisov, A.Kh. Bikulov, S.K. Nechaev, Random Hierarchical Matrices: Spectral Properties and Relation to Polymers on Disordered Trees, J. Phys. A 42, (2009) 075001

[75] V.A. Avetisov, A. Chertovich, S.K. Nechaev, O. Vasilyev, On scale free and poly-scale behaviors of random hierarchical networks. J. Stat. Mech.: Theory and Experiment. J. Stat. Mech. (2009) P07008

[76] V.A. Avetisov, A.V. Chertovich, S.K. Nechaev, O.A. Vasilyev, Some physical applications of random hierarchical matrices, Journal of Experimental and Theoretical Physics, 109 (2009) 485

[77] V. A. Avetisov, S. K. Nechaev, Chaotic Hamiltonian systems: Survival probability, Phys. Rev. E 81, 046211 (2010)

[78] V.A. Avetisov, S.K. Nechaev, A.B. Shkarin, On the motifs distribution in random block-hierarchical networks, Physica A, 389 (2010) 5895-5902

[79] K. Khanin, S. Nechaev, G. Oshanin, A. Sobolevski, O. Vasilyev, Ballistic deposition patterns beneath a growing KPZ interface, Phys. Rev. E, 82, 061107 (2010)

[80] M. Tamm, S. Nechaev, S. N. Majumdar, Statistics of layered zigzags: a two-dimensional generalization of TASEP, J. Phys. A, 44 (2011) 012002

[81] S. Nechaev, M. Tamm, O. Valba O.V., Statistics of noncoding RNAs: alignment and secondary structure prediction, J. Phys. A, 44 (2011) 195001

[82] A. Gorsky, S. Nechaev, R. Santachiara, G. Schehr, Random ballistic growth and diffusion in symmetric spaces, Nuclear Physics B 862 [FS] (2012) 167-192

[83] O.V. Valba, S.K. Nechaev, M.V. Tamm, Alignment of RNA molecules: Binding energy and statistical properties of random sequences, J. Exp. Theor. Phys. 114, 354 (2012)

[84] O.V. Valba, M.V. Tamm, S.K. Nechaev, New Alphabet-Dependent Morphological Transition in Random RNA Alignment, Phys. Rev. Lett. 109, 018102 (2012) [5 pages]

[85] O. Valba, S. Nechaev, M. Tamm, Interaction of RNA molecules: Binding energy, and comparison of random sequences, Chemical Physics 31, 23-27 (2012) [in Russian]

[86] A. Gorsky, S. Nechaev, V. S. Poghosyan, V. B. Priezzhev, From elongated spanning trees to vicious random walks, Nucl. Phys. B 870 [FS] (2013) 55-77

[87] S.K. Nechaev, A.N. Sobolevski, O.V. Valba, Planar diagrams from optimization for concave potentials, Phys. Rev. E 87, 012102 (2013) [9 pages]

[88] A.Y. Lokhov, S.K. Nechaev, M.V. Tamm, O.V. Valba, New phase transition in random planar diagrams and RNA-type matching, Phys. Rev. E 88, 052117 (2013) [7 pages]

[89] V.A. Avetisov, V.A. Ivanov, D.A. Meshkov, S.K. Nechaev, Fractal globule as a molecular machine, JETP Letters, 98 (2013) 270-274

[90] D.A. Meshkov, V.A. Ivanov, S.K. Nechaev, V.A. Avetisov, Relaxational dynamics of crumpled globule, Chemical Physics, 33, 47-52 (2014) [in Russian]

[91] M.V. Tamm, A.B. Shkarin, V.A. Avetisov, O.V. Valba, S.K. Nechaev, Islands of stability in motif distributions of random networks, Phys. Rev. Lett. 113 (2014), 095701

[92] L. Nazarov, S.K. Nechaev, M.V. Tamm, Lamplighter model of random copolymer adsorption on a line, Cond. Mat. Phys. 17 (2014), 33002

[93] N. Haug, S. Nechaev, M. Tamm, From generalized directed animals to the asymmetric simple exclusion process, J. Stat. Mech. (2014) P-10013

[94] V.A. Avetisov, V.A. Ivanov, D.A. Meshkov, S.K. Nechaev, Fractal Globules: A New Approach to Artificial Molecular Machines, Biophysical J. 107 (2014), 2361-2368

[95] A.Y. Lokhov, O.V. Valba, M.V. Tamm, S.K. Nechaev, Topological transition in disordered planar matching: combinatorial arcs expansion, J. Stat. Mech. (2014) P-12004

[96] V. A. Avetisov, S. K. Nechaev, Fractal polymer globules: A new insight on prebiological evolution, Geochemistry International, 52 (2014) 1252-1259

[97] V.A. Avetisov, L. Nazarov, S.K. Nechaev, M.V. Tamm, A statistical model of intra-chromosome contact maps, Soft Matter 11 (2015), 1019-1025

[98] M. Imakaev, L. Mirny, S. Nechaev, Effects of topological constraints on globular polymers, Soft Matter 11 (2015), 665-671

[99] Olga V. Valba, Sergei K. Nechaev, Mark G. Sterken, L. Basten Snoek, Jan E. Kammenga and Olga O. Vasieva, On predicting regulatory genes by analysis of functional networks in C. elegans, BioData Mining, 8 (2015) 33 [16pp]

[100] K. Bulycheva, A. Gorsky, S. Nechaev, Critical behavior in topological ensembles, Phys. Rev. D 92 (2015) 105006

[101] A.Y. Grosberg, S.K. Necheav, From statistics of regular tree-like graphs to distribution function and gyration radius of branched polymers, J. Phys. A: Math. Theor., 48 (2015) 345003

[102] V. Avetisov, P. Krapivsky, S. Nechaev, Native ultrametricity of sparse random ensembles, J. Phys. A: Math. Theor., 49 (2016) 035101

[103] V. Avetisov, A. Gorsky, S. Nechaev, O. Valba, Spontaneous symmetry breaking and phase coexistence in two-color networks, Phys. Rev. E, 93 (2016) 012302

[104] Alexander Gorsky, Alexey Milekhin, Sergei Nechaev, Douglas-Kazakov on the road to superfluidity: from random walks to black holes, arXiv:1604.06381

[105] S. Nechaev, K. Polovnikov, From geometric optics to plants: eikonal equation for buckling, Soft Matter, 13 (2017) 1420-1429

[106] V. Avetisov, M. Hovhannisyan, A. Gorsky, S. Nechaev, M. Tamm, O. Valba, Eigenvalue tunnelling and decay of quenched random networks, Phys. Rev. E 94 (2016) 062313

[107] S.K. Nechaev, Concepts of polymer statistical topology, arXiv:1608.06529, to appear in “Topology in Condensed Matter Physics” (ed. S. M. Bhattacharjee), 2017

[108] V. Kovaleva, Yu. Maximov, S. Nechaev, O. Valba, Peculiar spectral statistics of ensembles of trees and star-like graphs, J. Stat. Mech., 073402 (2017)

[109] S.K. Nechaev, M.V. Tamm, and O.V. Valba, Paths counting on simple graphs: from escape to localization, J. Stat. Mech., 053301 (2017)

[110] V. Avetisov, A. Gorsky, S. Nechaev, O. Valba, Many-body localization and new critical phenomena in regular random graphs and constrained Erdos-Renyi networks, arXiv:1611.08531, to appear in Phys. Rev. E

[111] S. Nechaev, K. Polovnikov, Number-theoretic aspects of 1D localization: "popcorn function" with Lifshitz tails and its continuous approximation by the Dedekind η, arXiv:1702.06757, to appear in Soviet Physics Uspekhi, 2017

[112] V. Avetisov, A. Gorsky, S. Nechaev, O. Valba, Finite plateau in spectral gap of polychromatic constrained random networks, arXiv:1705.00233, to appear in Phys. Rev. E

[113] S.K. Nechaev, Non-Euclidean geometry in nature, arXiv:1705.08013, to appear in "Order, Disorder and Criticality", (ed. Y. Holovatch), WSPC, 2018

[114] K. Polovnikov, S. Nechaev, M. Tamm, Memory-dependent quadratic action for fractal Brownian motion, arXiv:1707.07153

[115] V. Avetisov, A. Gorsky, S. Maslov, S. Nechaev, O. Valba, Social behavior beyond the Schelling model, in preparation