Curriculum Vitae

Vladimir Salnikov

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Qualification :

Qualified for the functions of Associate Professor:

- French NUC section 25 - Mathematics, qualification N° 13225236900;
- French NUC section 26 - Applied mathematics and applications of mathematics, qualification N° 13226236900.

Key words :

Dynamical systems and dynamical integrability: algebraic, topological,
and numerical approaches; modeling and control.
Generalized geometry and super geometry.
Geometry and quantization of sigma models, supersymmetric sigma models.

Modelling: thermodynamic equilibrium for biological simulations;
mechanical, thermal and electric properties of composites.

Numerical aspects: GPU and parallel computing;
Applications : physics, mechanics, informatics, biology, signal and image analysis.

Contents

1 Curriculum vitae

Present position

Since 2013 Postdoctoral researcher
Nicolas Oresme Mathematics Laboratory (GM3N group)
University of Caen Lower Normandy

Professional experience

2012 - 2013 Teaching and research fellow
(Attaché temporaire d'enseignement et de recherche)
LMI – Mathematics laboratory
of the National Institute of Applied Sciences – INSA de Rouen

2011 - 2012 Teaching and research fellow
(Attaché temporaire d'enseignement et de recherche)
Institut Camille Jordan
Université Claude Bernard Lyon 1

2008 - 2012 Ph.D. student under the supervision of Prof. T.Strobl,
(Allocataire de recherche de MESR, Moniteur)
Institut Camille Jordan
Université Claude Bernard Lyon 1
Thesis: *Gauged Sigma Models and Graded Geometry*
defended on the 26 of September 2012 in Lyon
Committee: A. Kotov, C. Roger, V. Roubtsov, H. Samtleben, T. Strobl

2008 - 2011 Ph.D. student under the supervision of Prof. S.Stepanov,
A.A.Dorodnitsyn Computing Center
of the Russian Academy of Sciences
Thesis: *Numerical methods of analysis of integrability of dynamical systems*
defended on the 23 of December 2011 in Moscow
Committee: S.Ya.Stepanov, I.I.Kosenko, A.S.Kuleshov, P.S.Krasil'nikov, V.Yu.Gidaspov, O.V.Kholostova, B.S.Bardin, A.M.Bishaev, V.A.Kotel'nikov, A.L.Kunitsyn, Yu.G.Markov, I.A.Mukhametzyanov, R.G.Mukharlyamov, U.G.Pirumov, D.L.Reviznikov, E.P.Skorokhod, V.F.Formalev, V.M.Churkin.

2003 - 2008 Teacher (Informatics, Mathematics), Educational Institution 1586,
Moscow, Russia

2004 - 2008 Head of the Informatics department, Educational Institution 1586,
Moscow, Russia

Education

2003-2008	Moscow State Lomonosov University, department of Mechanics and Mathematics, specialization: Mathematics (Specialist degree obtained), diploma thesis: "On various approaches to analysis of integrability of dynamical systems", graduated with honors.
2006-2007	Master second year, research, Unité de mathématiques pures et appliquées, Ecole normale supérieure de Lyon (Master degree obtained), diploma thesis: "Comparaison des deux approaches à la non-intégrabilité".
2001-2003	Advanced Education Scientific Center of Moscow State University – Kolmogorov school, specialization in biophysics (graduated with honors).

Languages and IT skills

- **Languages :**
  English (fluent), French (fluent), Russian (native), German (basic notions).

- **Information technology :**
  - Programming : C/C++, Pascal, CUDA, Maple, Matlab, Code Aster, Salome;
  - Web: HTML, JavaScript, PHP.
  - LaTeX, Office (Word, Excel, PowerPoint and "open source" analogues).
  - Operating systems : Windows/Windows Server, Linux, bases of MacOS.

2 Research activities

Publications and communications

- 13 articles published (or accepted) including: 8 in journals, 5 in refereed proceedings; 4 articles submitted to international journals and 2 in preparation.
See page 6 for the full list.
- Participation in 66 conferences, workshops and schools, including 35 with communication and 4 as an invited speaker. See the full list in the appendix – page 18.

Collaboration

- P. Karamian – LMNO, Université de Caen Basse-Normandie
- D. Choï – LMNO, Université de Caen Basse-Normandie
- W. Respondek – LMI INSA de Rouen
- C. Le Guyader – LMI INSA de Rouen
- T. Strobl – ICJ, Université Claude Bernard Lyon 1
- S.Ya. Stepanov – A.A.Dorodnitsyn Computing Center of the Russian AS
- A. Tsygvintsev – UMPA ENS de Lyon
- D. Sinitsyn – N.N.Semenov Institute of Chemical Physics of the Russian AS
- J.-P. Michel – Université de Louvain et Liège
- A. Kotov – University of Tromsø
- G. Bonavolonta – Université de Luxembourg
- V.L. Golo – Dept. of Mechanics and Mathematics of Moscow State Lomonosov University
- K.V. Shaitan – Dept. of Biology of Moscow State Lomonosov University

For the details of the collaboration subjects see the research topics below (page 8) and the description of research interests (part 7).

Scientific stays abroad

Sept. – Nov. 2010	The International Erwin Schrödinger Institute (ESI) for mathematical physics Program "Higher Structures in mathematics and physics", supported by the ESI Junior Fellowship – Vienna, Austria.
Nov. 2007	Collaboration with Ruhr-Universität Bochum, within the framework of the "Euler" project – Bochum, Germany.

Reviewing acivities

- Referee for The Journal of Geometry an Physics
- Referee for The Scientific World Journal
- Reviewer for Mathematical Reviews/MathSciNet

Publications and pre-publications[1]

Published or accepted articles

In international journals

13. V.Salnikov, D.Choi, P.Karamian-Surville, On efficient and reliable stochastic generation of RVEs for analysis of composites within the framework of homogenization to appear in Computational Mechanics, 2015. Preprint: arXiv:1408.6074.
12. A.Kotov, V.Salnikov, T.Strobl, 2d Gauge Theories and Generalized Geometry, to appear in Journal of High Energy Physics, 2014;
11. V.Salnikov, Graded geometry in gauge theories and beyond, to appear in Journal of Geometry and Physics, 2014;
10. V.Salnikov, Effective algorithm of analysis of integrability via the Ziglin's method, Journal of Dynamical and Control Systems, March 2014. DOI: 10.1007/s10883-014-9213-z. Preprint: arXiv:1208.6252 [math.DS];
9. V.Salnikov, On numerical approaches to the analysis of topology of the phase space for dynamical integrability, Chaos Solitons & Fractals, Vol. 57, Dec. 2013; Preprint: arXiv:1206.3801 [math.DS];
8. V.Salnikov, T.Strobl, Dirac Sigma Models from Gauging, Journal of High Energy Physics. 11/2013; 2013(11). DOI:10.1007/JHEP11(2013)110.
1. V.L.Golo, Vl.N.Salnikov, and K.V.Shaitan, Harmonic Oscillators in the Nosé-Hoover Environment, Physical Review, E70, 046130, 7 pages, 2004.

In other journals

7. V.Salnikov, Intégrabilité dynamique: de l'approche algébrique au calcul parallèle, Matapli (SMAI) N°100, 2013 (in French).

In refereed proceedings

6. Vl.N.Salnikov, *The possibilities of using the school informatics laboratory in realization of the "interaction" between various profiles of education*, Special volume of the digest "Realization of the lyceum education" for the proceedings of the "Round table" on the Realization of the lyceum education, 6 pages, 2008, (in Russian).
5. Vl.N.Salnikov, *On the dynamics of a triple pendulum: Various approaches to non-integrability*, Proceedings of the Contest-Conference for Young Scientists, Institute of Mechanics of MSU, 4 pages, 2007, (in Russian).
4. Vl.N.Salnikov, *On the dynamics of the triple pendulum: non-integrability, topological properties of the phase space*, Lecture notes of The Conference "Dynamical Integrability", 11 pages, 2006, published on the CD.

[1]Numbering in chronological order.

3. V.N.Salnikov, *Nonlinear Dynamics in the Nosé-Hoover Environment*, Proceedings of the Fifth EUROMECH Nonlinear Dynamics Conference, 12 pages, 2005, publ. on the CD.
2. Vl.N.Salnikov, *Nonlinear Dynamics and Resonance Effects of Systems in the Nosé-Hoover Thermostat*, Proceedings of the Contest-Conference for Young Scientists, Institute of Mechanics of MSU, 4 pages, 2004 (in Russian).

Articles submitted to international journals

14. V.N.Salnikov, On nonlinear dynamics of double and triple pendula: various aspects of integrability;
15. V.Salnikov, Integrability of the double pendulum - the Ramis' question, arxiv:1303.4904 [math.DS];
16. V.Salnikov, S.Lemaitre, D.Choi, P.Karamian-Surville, Measure of combined effects of morphological parameters of inclusions within composite materials via stochastic homogenization to determine effective mechanical properties, Preprint: arXiv:1411.4037
17. V.Salnikov, D.Choi, P.Karamian, S.Lemaitre, Génération de VER 3D par la dynamique moléculaire et variations autour de la pixellisation. Calcul des propriétés effectives des composites.

Articles in preparation

18. Supersymmetric AKSZ sigma models (en collaboration avec J.-P.Michel, G.Bonavolonta et T.Strobl)
19. Measure of combined effects of morphological parameters and the random distribution of inclusions of type spheres-cylinders within composite materials via stochastic homogenization to determine effective thermal and electric properties, (en collaboration avec D.Choi, P.Karamian, S.Lemaitre)

Research topics

Below are the main subjects of my research, they are also detailed in part 7.

LMNO – Université de Caen Basse-Normandie
Period: 2013 –

- Generalized geometry in gauge theories – collaboration with T.Strobl, A.Kotov.
- Improvement of thermal and electric conductivity of composites within the framework of stochastic homogenization – collaboration with P.Karamian, D.Choï (ACCEA project).

Mathematics laboratory – INSA de Rouen
Period: 2012 – 2013.

- Dynamical systems: efficient implementation of the algorithms of qualitative analysis; Numerical aspects: GPU et parallelization.
- Integrability and control theory – collaboration with W.Respondek
- Applications of the qualitative analysis of dynamical systems to problems from biology and physics – collaboration with A.Tsygvintsev.
- Computation on the graphical processors and parallelization in imaging – collaboration with C.Le Guyader.

Institit Camille Jordan – Université Claude Bernard Lyon 1
Period: 2008 – 2012.

- Generalized geometry and super geometry: application to the sigma models – collaboration with T.Strobl
- Supersymmetric models – collaboration with T.Strobl, J.-P.Michel, G.Bonavolonta.

A.A.Dorodnitsyn Computing Center of the Russian Academy of Sciences
Period: 2008 – 2011.

- Dynamical systems and dynamical integrability: algebraic, geometric and topological approaches.
- Dynamical integrability: possibilities of employing the numerical methods – collaboration with S.Stepanov.

Department of pure and applied mathematics
of the École Normale Supérieure de Lyon
Period: 2006 – 2007.

- Dynamical systems and dynamical integrability: algebraic and topological approaches – collaboration with A.Tsygvintsev
- Quantization problems – collaboration with T.Strobl.

Department of Mechanics and Mathematics of the Moscow State University
Period: 2003 – 2008.

- Dynamical integrability of mechanical systems, geometric and topological approaches – collaboration with V.L.Golo.
- Modeling of the thermodynamic equilibrium for biological simulations – collaboration with V.L.Golo, K.V.Shaitan and the group of molecular simulations of the Moscow State University: `http://www.molsim.org/`

3 Teaching activities

As a **vacataire** (teaching assistant) at INSA de Rouen:

2014-2015 lectures and exercises on Algebra I semester –
– 1st year, International bilingual section, (64 hours).

2013-2014 lectures and exercises on Numerical analysis –
– 3d year of the Mathematics department (9 + 21 hours).

As an **ATER** (teaching and research fellow) at INSA de Rouen (192 hours):

2012-2013 lectures and exercises on "Linear optimization/programming" –
– 4th year of the Mathematics department (18 + 36 hours)
exercises of "Algebra I semester" (42 hours)
exercises of "Algebra I semester" at the international bilingual section
– in English (42 hours)
complementary courses of Algebra and Analysis (18 hours)
Practical projects - 3rd and 4th year of the Mathematics department (36 hours).

As an **ATER** (teaching and research fellow) at the ICJ Université Claude Bernard Lyon 1 (half-time – 96 hours):

2011-2012 exercises of "Basic mathematical techniques I semester" for physicists/chemists, 2 groups, 39 hours each.
and collaboration with the "Handicap Mission"

As a **moniteur** (teaching assistant) at the ICJ Université Claude Bernard Lyon 1 (64 hours/year):

2010-2011 exams of "Algebra IV semester" for mathematicians 18 hours.

2009-2010 exercises of "Basic mathematical techniques I semester" for physicists/chemists, 2 groups, 36 hours each.

2008-2009 exercises of "Analysis IV semester" for physicists 36 hours.

2008-2009 exercises with integrated lectures of "Analysis I semester" for mathematicians 45 hours.

As a **teacher** at the Educational Institution 1586 (Moscow):

2003-2008 in parallel to my university studies in Moscow
I was teaching Information Technology (Equivalent level: graduating classes and first years of university $\sim$ full time, 220 – 700 hours):
– lectures, exercises and practical classes of IT,
– lectures, exercises and practical of programming (C/C++, Pascal),
– lectures on higher mathematics adapted to last grades of the lyceum,
– specialized courses on programming applied to computer modelling in science.

Diffusion of scientific knowledge

- Organization of the exhibition "Pourquoi les mathématiques ?" ("Why maths?"), Moscow, Russie, 2012
- Participation in organization of the "fête de la science" ("festival of science"), Lyon, 2011.

For the detailed description of my teaching activities see my web-page.

4 Administrative activities and collective responsibility

Organization

- *International workshop on Integrability in Dynamical Systems and Control*, **DISCo–2012** Rouen, France, 2012, (`http://math.univ-lyon1.fr/~salnikov/disco/`): ∼40 participants; financed in part by 'Lavrentiev 2012' prize of the French embassy in Russia.
- *Exhibition "Pourquoi les mathématiques ?"* ("Why maths ?"), Moscow, Russia, 2012 (`http://www.mathexpo.ru/`): 7 weeks, ∼ 5000 visitors.
- *International Workshop on Gauge Theories, Supersymmetry and Mathematical Physics*, Lyon, France, 2010 (`http://math.univ-lyon1.fr/~salnikov/gtsmp/`): ∼40 participants.
- *Conference on problems of quality of scientific education in higher grades*, Moscow, Russia, 2008 : ∼50 participants.

Administration

- 2014–2015: Responsible for the course "Algebra" in International Bilingual Section (1st year) at INSA de Rouen.
- 2012-2013: Responsible for the course "Optimisation linéaire" (4th year of Department of Mathematics) at INSA de Rouen.
- 2004-2008: Head of the Informatics Department – Educational institution 1586 in Moscow for 4 years, with the setup of the courses in informatics and mathematics. The experience of this activity is described in [6], cited in the list of publications.

5 Scholarships, grants and distinctions

- *'Lavrentiev 2012' prize*, French embassy in Russia (Project on the organization of a conference and on using the GPU for parallel computing).
- Erwin Schrödinger International Institute for Mathematical Physics (ESI) Vienna Austria: Junior Fellowship 2010.
- "Euler" project: Collaboration of the Moscow State Lomonosov University with Ruhr-Universität Bochum, 2007.
- Scholarship of École Normale Supérieure de Lyon for master studies (2nd year research) and internship (2006 – 2007 academic year).
- The Moscow government award "for success in the field of science and technology in education".
- The "New generation" prize established by RAO "UES of Russia".

6 Miscellaneous

- Participation in Semaine d'Étude Mathématiques et Entreprises (SEME – week of mathematical and industrial studies) : 4th edition, (supported by GDR CNRS Mathématiques et Entreprises and AMIES).Problem from EADS : "Realization of the catalog of spacial debris" proposed by Max Cerf.
- 1st prize of the "Trophée" of the Jeunes Ambassadeurs de Lyon, promotion 2006-2007 for the project of mathematical olympiads "Lyon-Moscou".

7 Research statement

Qualitative analysis of dynamical systems

Motivations

My interest to this subject was inspired by some non-linear effects observed in the numerical simulations of the mechanical systems with constraints within the framework of the study of their thermodynamical properties. We have started by analysis of such systems even not couples to the environment, namely by analysis of their integrability.

The question of integrability of dynamical systems has been studied seriously since the middle of the XIX century. At that time the main property of the systems of ordinary differential equations that was interesting for the mathematicians was *integrability by quadratures*, i.e. the possibility to obtain a solution of a given system of ODE by inverting the functions and computation of the primitives. There are two important properties of the system that can simplify the solution of this problem: the existence of a continuous group of symmetries of the system (Noether theorem), and the existence of the functions constant along the trajectories – the first integrals (Liouville-Arnold theorem) (see e.g. *"Symmetries, Topology and Resonances in Hamiltonian Mechanics"* by V.V. Kozlov, Springer, 1996, for a review of the results).

These observations have been regrouped in the "modern" definition of integrability in the Liouville–Arnold's sens, namely the systems with n degrees of freedom should possess n independent first integrals commuting in the sens of the Poisson bracket. This formulation permits to profit from the powerful tools of the symplectic geometry and complex analysis to study the qualitative behaviour of the systems of ordinary differential equations. Integrable systems are in some sens more regular. That is for such a system it is reasonable to discuss perturbations and stability. But if the system is not integrable (and the majority of the systems are not), it means that its behaviour is qualitatively complicated and one can expect the presence of non-linear effects, chaotization, etc.

So there are two natural directions of the study of dynamical systems: the search of non-artificial integrable systems and the rigorous proof of non-integrability of the systems interesting for applications. My research in the domain concerns both problems, as well as the relations that one can establish via geometry between integrability, qualitative behaviour of dynamical systems in general and control theory in particular. An important part also addresses the efficient implementation of the methods and applications in physics, mechanics and biology.

Results and work in progress

The major part of this work has been done within the framework of my studies at the ENS de Lyon, the Moscow University and of my Ph.D. thesis in the Computing Center of the Russian Academy of Sciences. This work is being continued in the Mathematics Laboratory of the INSA de Rouen.

Topology of integrable systems.

The first natural question to be asked in the context of integrability concerns hamiltonian systems with two degrees of freedom. We have developed a rather general method to visualize the phase space to test the existence of additional first integrals for the systems that can be reduced to the phase space of small dimension ("method of sections", [7]).

We have suggested a generalization of the "method of sections" ([4]), based on the results of the Kolmogorov–Arnold–Moser theory, to analyze the real integrability of systems with parameters. This method permits in particular to localize the possible integrability regions in the parameter space.

Algebraic methods.

Since for a given dynamical systems there is no general known criteria of integrability, a natural idea is to restrict the class of "admissible" first integrals. For example one can consider the class of polynomial functions or ones admitting a meromorphic continuation; that is rather natural since for known integrable systems such a situation often takes place. This permits to employ advanced algebraic methods, namely to study algebraic groups associated to variational equations along a particular solution of the initial system. A rather detailed review can be found for example in *"Hamiltonian systems and their integrability"* by M. Audin (Cours Spécialisés, SMF et EDP Sciences, 2001). The key idea is that for an integrable systems some groups (the monodromy group in the approach of S.L.Ziglin and the differential Galois group in the approach of J.Morales and J.-P.Ramis) cannot be too complicated, and even often should be commutative.

The approaches of Ziglin and Morales–Ramis need an explicit particular solution of the dynamical system. Since for a given solution the differential Galois group contains the monodromy group, it is considered that the Morales–Ramis method is stronger than the Ziglin's one. We have considered the possibility to use a trajectory obtained numerically to construct the monodromy group and apply the latter method which is qualitatively more comprehensible. This permits to formulate an effective algorithm to search for the obstructions to meromorphic integrability ([3]). It is rather natural to suggest the usage of numerical methods of this type to study the properties of dynamical systems, but there are surprisingly few works on the subject, all addressing rather the computation of the groups along a known solution. Our approach permits to overcome also the difficulty of construction of this particular solution, allowing in addition multivalued solutions.

Applications and efficient implementation.

We have applied these two methods to analyze the integrability of systems having mechanical origin. Namely we have shown that the pendulum-type systems are integrable only in the trivial cases when the systems decouples to parts of smaller dimension. We have also shown the non-integrability of the double pendulum with gravity, of the axisymmetric satellite, and the Henon-Heiles system ([2 – 4, 6, 7]).

There are also some activities in progress related to this research topic. In particular they concern the qualitative analysis of the systems coming from "relativistic" celestial mechanics and modelling in biology. The first one is the consideration of a natural modification of the problem of gravitating bodies with a finite speed of propagation of interaction, that results

in a dynamical system with delay. And the first natural question is to classify the possible bounded solutions. In the classical case they correspond to the trajectories more regular than the generic ones. In what concerns the problem from biology, this is the analysis of the models of population dynamics adapted recently also to the simplified description of the immune reaction in the context of cancer-type diseases. For these systems an important problem is to search for the stationary points or the solutions of the limit-cycle type. For these examples the mentioned effects can be revealed be the methods described above.

Since the discussed methods are partially based on the numerical computations one should not neglect the implementation details. We have applied the CUDA technology of parallel programming for the GPU, that seems to be an optimal solution on this case ([1]).

Other directions.

The work in progress concerns mainly the links between the integrability and other domains of qualitative analysis of dynamical and control systems. We study the generalization of the approach of [3] for the differential Galois group as well as for the q-difference equations. We also explore the relation between the general theory of integration of algebroids with the approach of B. Malgrange to dynamical integrability For the control theory we study the flat systems and the link between flatness and integrability in the Frobenius sens, namely we would like to formulate a constructive method of verifying and eventually visualizing the flatness propoerty.

Diffusion

1. V.Salnikov, *Intégrabilité dynamique: de l'approche algébrique au calcul parallèle*, Matapli (SMAI), N° 100, 2013 (in French).

2. V.Salnikov, *Integrability of the double pendulum - the Ramis' question*, arxiv:1303.4904 [math.DS].

3. V.Salnikov, *Effective algorithm of analysis of integrability via the Ziglin's method*, Journal of Dynamical and Control Systems, March 2014 DOI: 10.1007/s10883-014-9213-z.

4. V.Salnikov, *On numerical approaches to the analysis of topology of the phase space for dynamical integrability*, Chaos, Solitons & Fractals, Vol. 57, Dec. 2013.

5. V.Salnikov, Ph.D. Thesis defended in the Computing Center of the Russian Academy of Sciences, 2011.

6. Vl.N.Salnikov, *On the dynamics of a triple pendulum: Various approaches to non-integrability*, Proceedings of the Contest-Conference for Young Scientists, Institute of Mechanics of MSU, 4 pages, 2007, (in Russian).

7. V.Salnikov, *On the dynamics of the triple pendulum: non-integrability, topological properties of the phase space*, Lecture notes of The Conference "Dynamical Integrability", 11 pages, 2006.

Generalized geometry in physical theories and beyond

Motivation

My research activity within the framework of this subject consists of a rather theoretical study related to the tools of modern differential geometry in the context of gauge theories.

The study of gauge theories is a subject rapidly developing since the middle of the twentieth century. On the one hand this is a powerful tool to explain the dynamics of elementary particles, permitting also to define quantization procedures; on the other hand this topic is often related to rich geometric structures and even motivates their definitions as it was the case for super geometry.

Independently of the applications to physical theories, graded geometry permits to give a unified description of several objects from modern geometry, such as vector bundles, symplectic and contact manifolds, algebroids, etc.

Results and work in progress

This subject interests me since my stay at the ENS de Lyon as a master second year student. This is also the main contents of my Ph.D. thesis defended in the Université Claude Bernard Lyon 1.

Graded and multigraded geometry

A Q-manifold is a graded manifold equipped with a homological vector field of degree 1, that we will call a Q-structure. One can associate natural Q-structures for example to a tangent bundle, a Poisson manifold, or more generally to a Lie algebroid. For the Q-manifolds we have defined a notion of equivariant Q-cohomology generalizing the description of ordinary equivariant cohomology via the Weil or the Cartan algebra.

We have also performed some constructions for multigraded manifolds, namely Q-structures, graded symplectic structures and measure compatible with this objects. This permits to formulate a possible generalization to multigraded case of the result of Aleksandrov–Kontsevich–Schwarz–Zaboronsky that states the existence of a symplectic structure on the space of maps between two graded manifolds equipped with some compatible geometric structure.

Sigma models.

In a very general sens, a sigma model is a functional on the space of maps between two manifolds equipped with some geometric structures. In the physical interpretation the starting manifold plays the role of the space-time and the arrival manifold (target) carries the information on the physical field content.

We have adapted a convenient approach of A.Kotov and T.Strobl to "encode" the essential ingredients of the sigma models employing the notions coming from the Q-manifolds and Q-bundles. This permits to obtain a geometric description of the symetries of the twisted Poisson sigma model (PSM, [3]) and the Dirac sigma model (DSM, [2]).

Inspired by the relation of gauging the Wess-Zumino term in the G/G WZW model with equivariant cohomology we implemented a likewise idea to the twisted PSM and the DSM ([2, 3]). Using the notion of equivariant Q-cohomology we have shown that (topological parts of) these models can be recovered from an equivariantly closed extension of the 3-form of the Wess-Zumino term. An important role in this context is played by an extension of the infinite dimensional Lie algebra corresponding to the Dirac structure. This Lie algebra describes the gauge transformations of the obtained models. The fact that the construction is rather similar for the twisted PSM and the DSM is related to the geometry of the Lie and Courant algebroids, as well as the Q-structures appearing naturally in the context. Moreover, the DSM is the most general sigma model in space-time dimension of 2 that can be obtained by gauging the symmetry group of the Wess-Zumino term ([5]).

Supersymmetric theories

For the supersymmetric sigma models the space-time or the target manifold can be naturally graded (before the introduction of the Q-formalism). The appropriate language for studying such theories is then the multigraded geometry. We have analyzed some supersymmetric gauge theories ([4]). After having properly defined all the objects from mathematical point of view, we showed for example that the world-sheet supersymmetric Poisson Sigma Model is on-shell equivalent to an ordinary PSM; and for the Chern-Simons theory one can find equivalent theories with supersymmetric world-sheet or target. We have also studied some supersymmetrization techniques and their relation to the generalization of the result of Aleksandrov–Kontsevich–Schwarz–Zaboronsky.

Other directions

The suggested idea of studying the cohomology of graded manifolds and Q-manifolds is rather general. There are natural applications in theoretical physics, for example it permits to construct gauge theories with a given symmetry group or study the obstructions to gauging ([5]). It is also useful for purely mathematical problems. There exists for example a non-trivial relation with the cohomology of Lie algebroids. It should also permit to recover within the framework of a general approach some characteristic classes obtained by physicists. The notion of equivariant Q-cohomology specializes to cohomology of Courant algebroids ([3]).

Diffusion

1. V.Salnikov, Ph.D. thesis defended in the Institut Camille Jordan Université Claude Bernard Lyon 1, 2012.
2. V.Salnikov, T.Strobl, *Dirac Sigma Models from Gauging*, Journal of High Energy Physics, 11/2013; 2013(11). DOI:10.1007/JHEP11(2013)110.
3. V.Salnikov, *Graded geometry in gauge theories and beyond*, to appear in Journal of Geometry and Physics 2014.
4. *Supersymmetric AKSZ sigma models*, in preparation – collaboration with J.-P.Michel, G.Bonavolonta and T.Strobl.
5. A.Kotov, V.Salnikov, T.Strobl, *2d Gauge Theories and Generalized Geometry*, to appear in Journal of High Energy Physics, 2014.

Modeling

Motivation.

With this project I started my research activities as a first-year student in the group uniting the Department of Mechanics and Mathematics and the Department of Biology of Moscow State Lomonosov University. One of the main goals was to develop an efficient tool for performing biological simulations (an extremely popular subject nowadays – cf. the Nobel Prize 2013 in chemistry). A part of this group was particularly interested in modeling of the thermodynamical equilibrium for molecular dynamics. Recently I have continued this activity in the Nicolas Oresme Mathematics Laboratory of the University of Caen.

Results and work in progress.

Molecular dynamics

Combining the analytical methods coming from the dynamical systems and numerical simulations we have characterized the range of applicability of so-called mechanical thermostats ([5]). Also some particular (sometimes non-physical) regimes of dynamics of systems confined to the Nosé-Hoover environment have been found ([4,6]), that is especially important for applications.

The difficulty of analysis within the framework of molecular dynamics is due to the size of the studied systems. The main challenge was to find the systems that are rather simple for theoretical analysis but sufficiently non-degenerate to observe the qualitative effects.

We managed to formulate the criteria of applicability of the mechanical thermostats and describe the effects that are observed in the 'incorrect' application. That was extremely useful for the further work of the group (`http://www.molsim.org/`) as well as for the molecular dynamics community in general.

Effective properties of composites

This work is being carried out within the project ACCEA (Amélioration des Conductivités des Composites pour Equipements Aéronautiques), selected by FUI 15 (Fonds Unique Interministériel). This applied project has a very precise goal to develop a composite material to fulfill the demands from aeronautical industry. Among the partners in this work we have several companies that are able to produce composite materials and provide microscopic and macroscopic measurements of sample. Our team is responsible for validation and eventual optimization of suggested solutions.

Even if we can not tell much more on the applied side of the project (because of the industrial confidentiality), we have obtained some purely scientific results on the methodology of analysis of effective properties of multiphase media, this gave rise to several publications. The main method that we have adopted is based on stochastic homogenization: the idea comes from the classical Monte Carlo Method. We study the samples with the same macroscopic parameters but with some variation of microstructural morphology – for each sample we compute effective properties and the finale result is the averaged value along the whole series. In this process there are two important stages: the generation of samples of a composite material (or data collection in the applications) and the computations of homogenized coefficients. For the first

problem we have developed and implemented a generation protocol, inspired in particular by the work [5]. In [1] we describe efficient procedures to generate a sample containing a mixture of inclusions of various geometries; on top of that we are able ([2]) to introduce imperfections and defects to inclusions in order to observe realistic physical effects. For the homogenization part we have adapted (and implemented) an FFT-based approach (cf. recent works of J.C. Michel, H. Moulinec, P. Suquet; V. Monchiet, G. Bonnet; D.G. Eyre, G.W. Milton). This allowed us to study the influence of morphology of inclusions on the effective mechanical ([3]) and thermal ([7]) properties. In addition we have collected a large data base that will be useful for applications, namely for estimation of parameters and resolution of various inverse problems.

Other directions

In what concerns the effective electromagnetic properties, another approach based on the analysis of percolating networks is in the process of development. We are also interested in possibilities of coupling the models in order to obtain an efficient and reliable description of thermomechanical and thermoelectric properties of composites, an even the transition effects.

Diffusion.

1. V.Salnikov, D.Choi, P.Karamian-Surville, On efficient and reliable stochastic generation of RVEs for analysis of composites within the framework of homogenization to appear in Computational Mechanics, 2015. Preprint: arXiv:1408.6074.
2. V.Salnikov, D.Choi, P.Karamian, S.Lemaitre, Génération de VER 3D par la dynamique mol eculaire et variations autour de la pixellisation. Calcul des propriétés effectives des composites, submitted.
3. V.Salnikov, S.Lemaitre, D.Choi, P.Karamian-Surville, Measure of combined effects of morphological parameters of inclusions within composite materials via stochastic homogenization to determine effective mechanical properties, submitted, Preprint: arXiv:1411.4037
4. V.N.Salnikov, *Nonlinear Dynamics in the Nosé-Hoover Environment*, Proceedings of the Fifth EUROMECH Nonlinear Dynamics Conference, 12 pages, 2005, publ. on the CD.
5. V.L.Golo, Vl.N.Salnikov, and K.V.Shaitan, *Harmonic Oscillators in the Nosé-Hoover Environment*, Physical Review, E70, 046130, 7 pages, 2004.
6. Vl.N.Salnikov, *Nonlinear Dynamics and Resonance Effects of Systems in the Nosé-Hoover Thermostat*, Proceedings of the Contest-Conference for Young Scientists, Institute of Mechanics of MSU, 4 pages, 2004 (en russe).
7. Measure of combined effects of morphological parameters and the random distribution of inclusions of type spheres-cylinders within composite materials via stochastic homogenization to determine effective thermal and electric properties, (en collaboration avec D.Choi, P.Karamian, S.Lemaitre)

Appendix. Participation in conferences and workshops.

Communications in conferences, workshops and schools

- *Journée "Simulation numérique et calcul intensif", le CRIHAN, Rouen, France, 2014 (oral comm.)*
- La sixième journée de la Fédération de Recherche Normandie-Mathématiques, Caen, France, 2014 (poster);
- *International Workshop "Dynamics & Kinetic theory of self-gravitating systems"* (IHP Gravasco trimester), Paris, France, (oral comm.);
- *Conference on Integrability, Topological Obstructions to Integrability and Interplay with Geometry* (CRM Research Program "Geometry and Dynamics of Integrable Systems"), Barcelona, Spain, 2013 (oral comm.);
- *Thematic week "Integrability and the newtonian N-Body Problem"*, (IHP Gravasco trimester), Paris, France, (invited lecturer);
- *2nd Conference on Finite Dimensional Integrable Systems*, CIRM Luminy, France, 2013 (poster);
- The 6th edition of the international conference Functional Equations in LIMoges, Limoges France, 2013 (oral comm.);
- International Workshop "Geometric Structures in Integrable Systems", Moscow, Russia, 2012 (invited lecturer);
- 8th European Solid Mechanics Conference, Graz, Austria, 2012 (oral comm.);
- La quatrième journée de la Fédération de Recherche Normandie-Mathématiques, Rouen, France, 2012 (poster);
- Dynamical systems and classical mechanics: a conference in celebration of Vladimir Arnold, Edinburgh, 2011 (poster).
- Research Workshop on Modern approaches to dynamical integrability, Portsmouth, England, 2011 (oral comm.);
- Workshop on Algebraic Geometry and Physics, Saint Jean de Monts, 2010 (oral comm.);
- III International Summer School on Geometry, Mechanics, and Control, L'Ametlla de Mar, Spain, 2009 (poster);
- Geneva-Lyon winter school, Les Diablerets, Switzerland, 2009 (oral comm.);
- Conference on problems of quality of scientific education in higher grades, Moscow, Russia, 2008 (oral comm., organization);
- Mathematical and Numerical Models for the Cardiovascular System, summer course, Cortona, Italy, 2008 (oral comm.);
- 5-th European Congress of Mathematics, Amsterdam, The Netherlands, 2008 (poster);
- "Round table" on the Realization of the lyceum education, Moscow, Russia, 2008 (oral comm.);
- Contest-Conference For Young Scientists - Institute of Mechanics, MSU, Russia, 2007 (oral comm.);
- Conference "Symmetry and Perturbation Theory", Otranto, Italy, 2007 (oral comm.);
- Conference "Dynamical Integrability", CIRM, Luminy, France, 2006 (oral comm.);

- Summer School "Contemporary Mathematics", Dubna (Ratmino), Russia, 2006 (assistant lecturer);
- 7-th Junior Mathematical Congress , Tg-Mures, Romania, 2006 (invited lecturer, scientific committee);
- Conference "Dynamics and Structure in Chemistry and Biology", Moscow, Russia, 2006 (oral comm.);
- Moscow-Bavarian Joint Advanced Student School on "Medical Imaging and Computer Simulations" and "Nanobiotechnology and Biosensors", Moscow, Russia, 2006 (invited lecturer);
- The Fifth Euromech Nonlinear Dynamics Conference, Eindhoven, The Netherlands, 2005 (oral comm.);
- XXXIII International Summer School-Conference "Advanced Problems in Mechanics", St. Petersburg, Russia, 2005 (poster);
- Conference "Dynamics and Structure in Chemistry and Biology", Moscow, Russia, 2005 (oral comm.);
- Conference "Mathematics, Computer, Education", Puschino, Russia, 2005 (oral comm. and poster);
- The Contest-Conference For Young Scientists - Institute of Mechanics, MSU, Russia, 2004 (oral comm., 2d degree diploma);
- Conference "Molecular Simulation Studies in Material and Biological Sciences", Dubna, Russia, 2004 (oral comm.);
- CEEPUS Computer Algebra Summer University, Miskolc, Hungary, 2004 (oral comm.);
- 6-th Junior Mathematical Congress, Stockholm, Sweden, 2004 (oral comm.);
- The 3-rd Kargin Conference "Polymers 2004", MSU, Russia, 2004 (oral comm.).

Participation in conferences, workshops and schools

- Winter School in Mathematical Physics, Les Diablerets, Switzerland, 2015;
- "Geometry and Mechanics", International Conference in honor of Charles-Michel Marle Paris, France, 2014;
- Winter School in Mathematical Physics, Les Diablerets, Switzerland, 2014;
- Bio-Dynamics-Day, LMAH-Le Havre Normandy, France, 2013;
- Journée d'Algèbre, GTIA, Caen, France, 2013;
- Winter School in Mathematical Physics, Les Diablerets, Switzerland, 2013;
- Biologie, Médecine & Systèmes Complexes – GdR "Dynamique et Contrôle des Systèmes Complexes", Rouen, France, 2012;
- International workshop on Integrability in Dynamical Systems and Control, DISCo–2012 Rouen, France, 2012 (organization);
- Recent Progress in Lagrangian & Hamiltonian Dynamics – A conference in honor of John Mather's 70th Birthday, Lyon, France, 2012;
- Winter School in Mathematical Physics, Les Houches, France, 2012.
- Symmetries, Integrable Systems and Representations, Lyon, France, 2011;
- Workshop on Covariant Field Theory, Luxembourg ville, Luxembourg, 2011;
- Journées de physique mathématique: Loop quantum gravity, Lyon, France, 2011;
- Poisson Geometry and Applications, Figueira da Foz (Coimbra), Portugal, 2011;
- Loop spaces, loop groups and loop algebras 2011, CIRM Luminy, France, 2011;
- Winter School in Mathematical Physics, Les Diablerets, Switzerland, 2011;
- School and conference on Higher Structures in mathematics and physics, within the ESI program, Vienna, Austria, 2010;
- International Workshop on Gauge Theories, Supersymmetry and Mathematical Physics, Lyon, France, 2010 (organization);
- Seminaire Borel (Winter School in Mathematical Physics), Les Diablerets, Switzerland, 2010;
- Conference Higher Structures in Mathematics and Physics, Zurich, 2009;
- Infinite Dimensional Lie Algebras, Geometry and Cohomology, (Conference in honor of Claude Roger for his 60th birthday), Lyon, France, 2009;
- First Meeting of the GDR "Quantum Dynamics", Lyon, France, 2009;
- Winter School on quantum chaos, Bordeaux, France, 2009;
- Summer school on Real and Symplectic Geometry, France, Paris, 2008;
- II International Summer School on Geometry, Mechanics, and Control, La Palma, Spain, 2008;
- Conference "Algebraic methods in dynamical systems", UPC, Barcelona, Spain, 2008;
- Conference "Geometrical Mechanics", CIRM, Luminy, France, 2007;
- Réunion LIOUVILLE, "Intégrabilité réelle et complexe en Mécanique Hamiltonienne", (IRMAR) Rennes, France, 2007;
- Workshop "Poisson sigma models, Lie algebroids, deformations, and higher analogues", ESI, Vienna, Austria, 2007;
- Thematic interdisciplinary school on "Perspectives in theory and technology of quantum information and communication", CIRM (Luminy), France, 2007;
- Workshop on Symplectic Geometry, Contact Geometry and Interactions, Lille, France 2007;