

# Mihai Nica

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## EMPLOYMENT

**2020 - now Assistant Professor**, University of Guelph

*Vector Institute Faculty Affiliate*

*CARE-AI Faculty Affiliate*

**2019 - 2020 Postdoctoral Fellow**, University of Toronto

**2017 - 2019 NSERC Postdoctoral Fellow**, University of Toronto

## EDUCATION

**2017 PhD, Courant Institute of Mathematical Sciences**, New York University

Advisor: Gérard Ben Arous

**2011 BMath, University of Waterloo**, Canada

Recipient of the Faculty of Mathematics Alumni Gold Medal for academic excellence

## REFEREED PUBLICATIONS

1. Li M and **Nica M**. (2024).  
“Differential Equation Scaling Limits of Shaped and Unshaped Neural Networks”  
*Transactions on Machine Learning Research*. [Open Review link](#).
2. Mohammad N, **Nica M**, Kraus D, Levere K M, and Okner R. (2024).  
“Student experience using synchronous and asynchronous learning in mathematics classes”  
*Pedagogical Research* 9(2) [DOI link](#).
3. Lyver, D\*, **Nica M**, Cot C, Cacciapaglia G, Mohammadi Z, Thommes E and Cojocaru M. (2024).  
“Population mobility, well-mixed clustering and disease spread: A look at COVID-19 spread in the United States and preventive policy insights”  
*Mathematical Biosciences and Engineering* 21(4):5604-5633 [DOI link](#).
4. Lasby M\*, Golubeva A, Evci U, **Nica M** and Ioannou Y. (2024).  
“Dynamic Sparse Training with Structured Sparsity”  
*International Conference on Learning Representations (ICLR) 2024*. [Open Review link](#).
5. Kreitzer M\*, **Nica M** and Pereira, R. (2023).  
“Using alternating de Bruijn sequences to construct de Bruijn tori”  
*Designs, Codes and Cryptography* [DOI link](#).
6. Floto G\*, Kremer S and **Nica M**. (2023).  
“The exponentially tilted Gaussian prior for variational autoencoders”  
*International Conference on Learning Representations (ICLR) 2023*. [Open Review link](#).
7. Mohammad N, Kraus D, Levere K M, **Nica M** and Okner R\*. (2023).  
“Promoting engagement via engaged mathematics labs and supportive learning”  
*International Electronic Journal of Mathematics Education* [DOI link](#).
8. Dauvergne D, **Nica M** and Virág B. (2023).  
“Uniform convergence to the Airy line ensemble”  
*Annales de l'Institut Henri Poincaré (B) Probabilités et Statistiques* 59(4): 2220-22256 [DOI link](#).
9. Galloway A\*, Golubeva A, Salem M\*, **Nica M**, Ioannou Y and Taylor G. (2022).  
“Bounding generalization error with input compression: An empirical study with infinite-width networks”  
*Transactions on Machine Learning Research*. [OpenReview link](#).

10. Li M\*, **Nica M** and Roy D. (2022).  
 “The neural covariance SDE: Shaped infinite depth-and-width networks at initialization”  
*Conference on Neural Information Processing Systems (NeurIPS) 2022*. [OpenReview link](#).  
 Oral-designated paper (Top 200 out of 2672 accepted papers)
11. Dauvergne D, **Nica M** and Virág B. (2022).  
 “RSK in last passage percolation: a unified approach”  
*Probability Surveys* 19:65-112. [DOI link](#).
12. Li M\*, **Nica M** and Roy D. (2021).  
 “The future is log-Gaussian: ResNets and their infinite-depth-and-width limit at initialization”  
*Conference on Neural Information Processing Systems (NeurIPS) 2021*. [OpenReview link](#).
13. **Nica M**. (2021).  
 “Intermediate disorder limits for multi-layer semi-discrete directed polymers”.  
*Electronic Journal of Probability*, 26:1-50. [DOI link](#).
14. Martin C\*, Zhang H\*, Costacurta J\*, **Nica M** and Stinchcombe A. (2021).  
 “Solving elliptic equations with Brownian motion: Bias reduction and temporal difference learning”.  
*Methodology and Computing in Applied Probability*, 24:1603-1626. [DOI link](#).
15. Han J\*, **Nica M** and Stinchcombe A. (2020).  
 “A derivative-free method for solving elliptic PDEs with deep neural networks”.  
*Journal of Computational Physics*, 419. [DOI link](#).
16. **Nica M**, Quastel J and Remenik D. (2020).  
 “One-sided reflected Brownian motions and the KPZ fixed point”.  
*Forum of Mathematics, Sigma*, 8:E63 [DOI link](#).
17. Hanin B and **Nica M**. (2020).  
 “Finite depth and width corrections to the neural tangent kernel”.  
*International Conference on Learning Representations (ICLR) 2020*, [OpenReview link](#)  
 Spotlight Presentation (Top 155 out of 697 accepted papers).
18. **Nica M**, Quastel J and Remenik D. (2020).  
 “Solution of the Kolmogorov equation for TASEP”.  
*Annals of Probability*, 48:2344–2358. [DOI link](#).
19. Hanin B and **Nica M**. (2020).  
 “Products of many large random matrices and gradients in deep neural networks”  
*Communications in Mathematical Physics*, 376:287–322. [DOI link](#).
20. Ben Arous G, Mei S, Montanari A and **Nica M**. (2019).  
 “The landscape of the spiked tensor model”.  
*Communications on Pure and Applied Mathematics*, 72:2282–2330. [DOI link](#).
21. Corwin I and **Nica M**.(2017).  
 “Intermediate disorder directed polymers and the multi-layer extension of the stochastic heat equation”.  
*Electronic Journal of Probability*, 22:1–49. [DOI link](#).
22. **Nica M**. (2017).  
 “Decorated Young tableaux and the Poissonized Robinson-Schensted process”.  
*Stochastic Processes and their Applications*, 127:449–474. [DOI link](#).

23. **Nica M.** (2016).  
“Optimal strategy in ‘Guess Who?’: Beyond binary search”.  
*Probability in the Engineering and Informational Sciences*, 30: 576–592. DOI [link](#).
24. Funk J, **Nica M** and Noyes M. (2015).  
“Stabilization time for a type of evolution on binary strings”.  
*Journal of Theoretical Probability*, 28: 848–865. DOI [link](#).
25. **Nica M.** (2011).  
“Eigenvalues and eigenfunctions of the Laplacian”.  
*The Waterloo Mathematics Review*, 1: 23–34. [Direct link](#).

## SUBMITTED PUBLICATIONS CURRENTLY UNDER REVIEW

1. Jakub C and **Nica M.** (2023).  
“Depth Degeneracy in Neural Networks: Vanishing Angles in Fully Connected ReLU Networks on Initialization ”  
Preprint [arXiv:2302.09712](#), 37 pages.

## GRANTS, FELLOWSHIPS AND OTHER FUNDING

- 2023** Investigator **NSERC Alliance Grant** ‘Discovery of Improved CO2 Capture Solvents by a Combination of Predictive Molecular-Based Simulation and Artificial Intelligence Algorithms’ with CanmetENERGY and Delta Cleantech. Principle Investigator: Monica Cojocaru. There are 7 total investigators on this grant.
- 2022** Investigator **NSERC Alliance Grant** “Modelling human behaviour response to public policy and its impact on infectious disease spread - case studies using AI/ML, data science, game theory and optimization” with Sanofi Pasteur Limited. Professor William R. Smith.
- 2022** Affiliate faculty **NSERC INTER-MATH-AI Grant**, Funding for graduate students working on mathematics of AI. \$ 44,000 in support to my graduate students in 2022-23.
- 2021-26** Principle investigator **NSERC Discovery Grant**, *Random Matrix Limit Theorems for Deep Neural Networks*, \$130,000
- 2020-22** Sub-contractor on **Guaranteeing AI Robustness against Deception (GARD)**, DARPA grant, sub-contracted under Prof. Graham Taylor.
- 2021** **PSEER Promoting Engagement Via Engaged Mathematics Labs and Supportive Learning** (joint with Prof. Nagham Mohammad and Prof. Kimberly Levere) \$4,000 [News link](#)
- 2017-19** **NSERC Postdoctoral Fellowship**, \$90,000. Held at the University of Toronto.
- 2011-16** **MacCraken Fellowship**, New York University, support for PhD studies
- 2011** **NSERC Canada Graduate Scholarship**, funding for PhD studies, [declined due to MacCraken fellowship rules]
- 2009** **Arthur Beaumont Memorial Scholarship**, University of Waterloo, awarded to an outstanding student in the Applied Mathematics Department
- 2008-10** **USRA Scholarship**, NSERC, awarded for undergraduate research (held three times)
- 2007-11** **William T. Tutte National Scholarship**, one of sixteen national scholarships awarded to incoming students in the Faculty of Mathematics at the University of Waterloo

## AWARDS & DISTINCTIONS

- 2020** **Vector Institute Postgraduate Affiliate Program**, Vector Institute [declined due to Guelph faculty position]
- 2018** **F. V. Atkinson teaching award**, honours outstanding teaching by post-doctoral fellows and other junior research faculty at the University of Toronto math department

- 2014 **Harold Grad prize**, awarded for outstanding performance and promise as a graduate student by the Courant Institute.
- 2011 **Alumni gold medal**, Awarded to one graduating student in the Faculty of Mathematics at the University of Waterloo in recognition of outstanding academic achievements
- 2010 **Putnam competition**, ranked in the top 220 out of 4,296 contestants
- 2010,11 **University of Waterloo applied math speaker award**, award for the best speaker among undergraduate researchers as voted by peers (awards in two consecutive years)
- 2008 **President's Research Award**, University of Waterloo, for undergraduate summer research

## CONFERENCE ORGANIZATION

- Jul 2023 Organizer for **High-dimensional Learning Dynamics Workshop**, Accepted at International Conference on Machine Learning (ICML) 2023, Hawaii, USA

## INVITED TALKS

- Apr 2024 **Infinite Depth-and-Width Limits of Neural Networks** McMaster Statistics Seminar, Hamilton
- Sept 2023 **Depth Degeneracy in Neural Networks**, AMS Eastern Sectional Meeting, Buffalo
- May 2023 **Depth Degeneracy and Vanishing Angles for Random Deep Neural Networks**, Politechnika Warszawska [Virtual]
- Feb 2023 **Depth Degeneracy in Neural Networks**, Probability Seminar, Centre de Recherches Mathématiques, Montreal
- Dec 2022 **The neural covariance SDE: shaped infinite depth-and-width networks at initialization**, NeurIPS 2022 deep dive session, New Orleans [Virtual]
- May 2022 **Random matrix problems in deep neural networks**, Politechnika Warszawska [Virtual]
- Apr 2022 **Random matrix problems in deep neural networks**, KTH, Sweden [Virtual]
- Feb 2022 **How do infinitely large neural networks behave?**, Vector Institute, Toronto [Virtual]
- Mar 2021 **Log-normal behaviour in deep neural networks and products of random matrices**, Probability Seminar, University of Waterloo, Waterloo [Virtual]
- Jan 2020 **A neural network method for solving elliptic and parabolic PDEs**, Modelling and Computational Science seminar, Ontario Tech University, Oshawa
- Nov 2019 **Scaling limits of deep neural networks**, University of Guelph, Guelph
- Jul 2019 **Gradients of ReLU networks on initialization**, Workshop on Theoretical Advances in Deep Learning at Istanbul Center for Mathematical Sciences, Istanbul
- Jun 2019 **Phase transitions in random matrices and the spiked tensor model**, Fields Institute workshop on Applications to Random Matrices and Free Probability, Toronto
- Mar 2019 **Deep neural networks and products of random matrices**, Workshop on Free Probability: the applied perspective, Centre de Recherches Mathématiques, Montreal
- Nov 2018 **A central limit theorem for deep neural networks and products of random matrices**, Centre de Recherches Mathématiques Probability Seminar, Montreal
- Nov 2018 **A central limit theorem for deep neural networks and products of random matrices**, Fields Institute Probability Seminar, Toronto
- May 2018 **On the complexity of random functions**, Physics of Information Lab, Applied Math Department, University of Waterloo
- Mar 2018 **Phase transitions in the spiked tensor model**, Colloquium, Department of Mathematics and Statistics, Queen's University
- Jan 2018 **Phase transitions in the spiked tensor model**, Fields Institute Probability Seminar, Toronto

- May 2017 Intermediate disorder limits for multi-layer random polymers**, University of Wisconsin Madison Probability Seminar
- Feb 2017 Intermediate disorder limits for multi-layer random polymers**, Northwestern University Probability Seminar
- Jan 2017 Intermediate disorder limits for multi-layer random polymers**, Probability Seminar at the Centre de Recherches Mathématiques, Montreal
- Sep 2016 Intermediate disorder limits for multi-layer random polymers**, Toronto Probability Seminar at the Fields Institute, Toronto
- Apr 2016 Intermediate disorder directed polymers and the multi-layer stochastic heat equation**, Finger Lakes Probability Seminar at Cornell University
- Nov 2015 Convergence of non-intersecting random walks**, AMS Sectional Meeting (special session on "Probability, Combinatorics, and Statistical Mechanics") at Rutgers University
- May 2015 Three ways to think about a certain model of vicious walkers**, Clay Math Institute Workshop on Random Polymers and Algebraic Combinatorics at University of Oxford
- Nov 2014 Exactly solvable Young diagram processes related to last passage percolation**, Northeast Probability Seminar at Columbia University
- Nov 2014 Exactly solvable Young diagram processes related to last passage percolation**, Cornell Probability Seminar at Cornell University
- Jul 2014 Exactly solvable Young diagram processes related to last passage percolation**, Seminar on KPZ at the University of California, Berkeley

## OTHER PRESENTATIONS

- Oct 2020 Computing moments of deep neural nets**, One World Probability Symposium, Online Conference [Virtual]
- Aug 2019 Adapting Inquiry Based Learning questions for large classrooms**, MAA Mathfest, Cincinnati
- Aug 2019 Starting a Calculus Community of Practice**, with Sarah Mayes-Tang, MAA Mathfest, Cincinnati
- Feb 2019 Overfitting and Regularization**, Ritual Technology Co. Data Science Workshop, Toronto
- Aug 2018 Gradients of neural nets and products of random matrices**, Poster presentation at workshop "Statistical Physics and Machine Learning back together", Institut d'Études Scientifiques de Cargèse, Corsica
- July 2017 Intermediate disorder limits for multi-layer random polymers**, Poster presentation at Park City Math Institute Random Matrices Workshop
- Nov 2016 Intermediate disorder limits for multi-layer random polymers**, Guest lecturer for advanced topics graduate course, University of California, Berkeley
- Sep 2016 Intermediate disorder limits for multi-layer random polymers**, Poster presentation, conference on "Quantum integrable systems, conformal field theories and stochastic processes" at Institut d'Études Scientifiques de Cargèse, Corsica
- Jul 2015 Random processes from the Robinson-Schensted-Knuth correspondence**, CRM-PIMS summer school at McGill University
- Jul 2014 Poissonized Robinson-Schensted tableaux**, Cornell Probability Summer School

## UNREFEREED NOTES AND VIDEO PRESENTATIONS

- Aug 2023 Terence Tao's central limit theorem, Double Factorials and the Moment Method** Video (~ 40 min) [YouTube link](#).  
Entry into 3Blue1Brown Summer of Math Exposition Contest 2023

- Aug 2022 Heads-Tails and Heads-Heads are different?**  
**The ABRACADABRA Theorem for coin flips and dice**  
 Video (~ 20 min) [YouTube link](#).  
 Top100 finalist in 3Blue1Brown Summer of Math Exposition Contest 2022  
 (Top 100 out of ~ 1000 entries)
- Jul 2022 Introduction to Infinite Neural Networks and the Neural Tangent Kernel**  
 Video series (~ 3 hours): These notes were used for a 4 week mini-course given at the Vector  
 Institute in Summer 2022.  
[YouTube link](#). Notes: [PDF link](#)
- Aug 2021 Why is pi here? Find  $\pi$  by Buffon's needle noodle!**  
 Video (~ 10 min) [YouTube link](#).  
 Honourable mention in 3Blue1Brown Summer of Math Exposition Contest 2021  
 (Top 30 out of ~ 1200 entries)
- Jun 2021 Introduction to Infinite Depth-and-Width Limits of Deep Neural Networks**  
 Video (~ 30 min): [YouTube link](#). Notes: [PDF link](#)
- Apr 2021 Binet's formula for the Fibonacci Numbers**  
 Videos (~ 1 hour): [YouTube link](#). Notes: [PDF link](#) and [link](#).  
 (Aimed at advanced high school/early undergrad audience)

## HIGHLY QUALIFIED PERSONNEL TRAINING

### UNDERGRADUATE RESEARCH SUPERVISION

- 2023 AI Methods for Solving Generalized Nash Equilibrium Problems**  
 Co-supervision with Prof. Monica Cojocaru.  
*Student:* Kira Tarasuk  
 Using AI methods such as gradient descent and neural networks to achieve solutions to  
 generalized Nash problems.
- 2022 A simple version of AlphaZero: Learning with self play in Connect Four**  
*Student:* Sam Vermeulen  
 Creating an AI agent that learns to play Connect 4 through a simplified version of the  
 AlphaZero algorithm. Research done for advanced undergraduate research project  
 MATH\*4600. Sam has continued on to do an MSc at Guelph. Code available at  
<https://github.com/sam-vermeulen/connectfourproject>.
- 2022 Fields Undergraduate Summer Research Program (FUSR): Boundary Integral  
 Equations with Random Walks and Reinforcement Learning.**  
 (Joint supervision with Prof. Adam Stinchcombe, University of Toronto)  
*Students:* Quinn Arbolante, Charles Beal, Amandin Chyba, Diba Heydary  
 Research on combining properties of random walks and ML methods to obtain numerical  
 solutions to certain PDEs.
- 2021 University of Guelph URA: Path Counting Approaches to Neural Net  
 Architecture Search.**  
*Student:* Valeria Telles  
 Research on using mathematical techniques to predict properties of neural network  
 architectures. Valeria plans to stay at the University of Guelph for an MSc with an anticipated  
 start date of F22.
- 2021 University of Guelph URA: Generalized Nash Games and AI methods.**  
 Co-supervision with Prof. Monica Cojocaru.  
*Student:* Nickolas Hoover  
 Research on applying neural network methods to generalized Nash games.

**2021 University of Guelph URA: Exponentially tilted Gaussian autoencoders.**  
(Informal mentorship and collaboration).

*Student:* Griffin Floto

Research on improving autoencoders and out of distribution detection for neural networks using exponentially titled Gaussian priors. This project continued a project that Griffin began with Professor S Kremer and began spontaneously when Griffin reached out to me. This led to our ICLR 2023 publication.

**2019 Fields Undergraduate Summer Research Program (FUSR): Machine Learning Methods for Numerical Solutions of Partial Differential Equations.**

(Joint supervision with Prof. Adam Stinchcombe, University of Toronto)

*Students:* Cameron Martin, Hongyuan Zhang and Julia Costacurta

FUSR is a competitive undergraduate research Funded by the Fields institute. I co-supervised a team of three undergraduate students. Our work led to the publication of a paper.

## GRADUATE STUDENT SUPERVISION

- PhD** Michal Lisicki W24-now. Co-supervised with Prof. Graham Taylor  
Distributional Reinforcement learning.
- MSc** Kira Tarasuk W24-now. Co-supervised with Prof. Monica Cojocar. Machine learning methods for Generalized Nash Equilibria.
- MSc** Sam Vermeulen W23-now.  
Solutions to Partial Differential Equations using reinforcement learning.
- PhD** Courtney Allen. F22-now. Co-supervised with Prof. Hermann Eberl.  
Using numerical methods to solve the anaerobic digestion model 1 with the inclusion of biofilms. Recipient of the INTER-MATH-AI funding \$20,000 per year.
- MSc** Valeria Telles. F22-now. Co-supervised with Prof. Bill Smith.  
Developing AI methods to speed up the search for more effective CO<sub>2</sub> capture solvents. Recipient of the INTER-MATH-AI funding \$12,000 per year.
- MSc** David Lyver. W22-now. Co-supervised with Prof. Monica Cojocar.  
Developing AI methods to predict and understand disease spread. Recipient of the INTER-MATH-AI PhD funding \$12,000 per year.
- PhD** Matthew Kreitzer. W22-now. Co-supervised with Prof. Rajesh Pereira.  
Generalization of DeBruijn Sequences
- MSc** Cam Jakub. F21-S23. *Recipient of the Vector Scholarships in Artificial Intelligence.*  
Research on infinite limits of deep neural networks.

## TEACHING ACTIVITIES

### AWARDS

- 2018 F. V. Atkinson teaching award**, honours outstanding teaching of post-doctoral fellows and other junior research faculty at the University of Toronto math department.

### COURSES TAUGHT

**Winter 2023 Instructor & coordinator**, MATH\*1030, Business Mathematics, University of Guelph

**Fall 2022, 23 Instructor**, DATA\*6100

Introduction to Data Science, University of Guelph.

My code examples for this course available at [GitHub link](#)

- Winter 2022, 24 Instructor**, MATH\*4060/MATH\*6181  
 Topics in Math: Introduction to Reinforcement Learning, University of Guelph.  
 My code examples for this course available at [GitHub link](#)
- Fall 2021, 22 Instructor**, UNIV\*6080, Computational Thinking for Artificial Intelligence, University of Guelph
- Fall 2020, 21 Instructor & coordinator**, MATH\*1200, Calculus 1, University of Guelph
- Winter 2019, 20 Instructor & coordinator**, MAT234, Differential Eqns for Mech. Eng., University of Toronto
- Winter 2019 Instructor**, MAT223, Linear Algebra 1, University of Toronto
- Fall 2018 Instructor**, MAT135, Calculus 1A, University of Toronto
- Winter 2018 Instructor**, MAT136, Calculus 1B, University of Toronto
- Fall 2017 Instructor**, MAT135, Calculus 1A, University of Toronto
- Summer 2016 Instructor**, Math-UA.121, Calculus I, New York University

## OTHER TEACHING ACTIVITIES

- Spring 2021** University of Guelph Virtual Interaction Conference on *Mysteries of the Fibonacci numbers*.
- Fall 2019 Instructor**, MAT1128HF, Topics in Probability. Introduction (6 hours of lectures) to a graduate course (11 students) on KPZ universality, University of Toronto. Notes available at [https://www.math.toronto.edu/mnica/KPZ\\_notes.pdf](https://www.math.toronto.edu/mnica/KPZ_notes.pdf)
- Fall 2019 TA Training Coordinator**, organize and run training workshops for 100 TAs at the University of Toronto
- Fall 2019 “Active Learning 101: A guide for new instructors in large classrooms”**, co-author (with Yvon Verberne and Melissa Emory) of a 17 page guide to creating active learning questions that work well in large classrooms. Available at [http://www.math.toronto.edu/mnica/CoP\\_Guide.pdf](http://www.math.toronto.edu/mnica/CoP_Guide.pdf)
- Summer 2019 “Adapting Inquiry Based Learning questions for large classrooms”**, Presentation at MAA Mathfest , Cincinnati
- Summer 2019 “Starting a Calculus Community of Practice”**, with Sarah Mayes-Tang, Presentation at MAA Mathfest, Cincinnati
- 2018-2019 Facilitator: Teaching Community of Practice**, organized and facilitated a Community of Practice for early career instructors at the University of Toronto
- 2012, 14 Courant Institute Written Exam Workshop** I ran a workshop for graduate students to study for the qualifying exams. <https://www.math.toronto.edu/mnica/#teaching>
- 2012-14 Volunteer Instructor** for Courant Splash (annual outreach program for high school students) <http://www.math.toronto.edu/mnica/csplash.html>