Justin Sirignano

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Academic Positions

Professor of Mathematics, University of Oxford — August 2024 -
Mathematical Institute

Associate Professor, University of Oxford — July 2020 - August 2024
Mathematical Institute

Assistant Professor, University of Illinois at Urbana-Champaign — 2016 - 2020
College of Engineering
Department of Industrial & Enterprise Systems Engineering
Coordinated Science Lab (Signals, Inference, and Networks group)

Chapman Fellow, Imperial College London — 2015 - 2016
Department of Mathematics

Education

Stanford University, PhD — 2010 - 2015

Princeton University, B.S.E. — 2006 - 2010
Graduated *summa cum laude*

Research Groups

The Mathematical Institute (Oxford's Department of Mathematics) consists of research groups covering a range of areas in mathematics. I am a faculty member in the following research groups:

- Stochastic Analysis
- Machine Learning & Data Science
- Mathematical & Computational Finance
- Oxford Centre for Industrial & Applied Mathematics (OCIAM)

Research Interests

- Applied Mathematics, Stochastic Analysis, and Optimization
- Mathematical analysis of machine learning/deep learning/AI models and algorithms, typically using methods from stochastic analysis.
- AI for Science (machine learning for scientific computing and PDE models)
- Mathematical finance

Selected Publications

1. "Kernel Limit of Recurrent Neural Networks Trained on Ergodic Data Sequences". S. Lam, J. Sirignano, and K. Spiliopoulos.
   The Annals of Applied Probability, 36 (3), 2014-2067, 2026.

2. "Mean Field Analysis of Neural Networks: A Law of Large Numbers." J. Sirignano and K. Spiliopoulos.
   SIAM Journal on Applied Mathematics, 80 (2), 725-752, 2020.

3. "Mean Field Analysis of Neural Networks: A Central Limit Theorem." J. Sirignano and K. Spiliopoulos.
   Stochastic Processes and their Applications, 130 (3), 1820-1852, 2020.

4. "Fluctuation Analysis for the Loss from Default." K. Spiliopoulos, J. Sirignano, and K. Giesecke.
   Stochastic Processes and their Applications, 124 (7), 2322-2362, 2014.

5. $*$ "DGM: A Deep Learning Algorithm for solving Partial Differential Equations." J. Sirignano and K. Spiliopoulos.
   Journal of Computational Physics, 375, 1339–1364, 2018.
   Contribution: High-dimensional PDEs are computationally challenging to solve using traditional numerical methods. This paper developed deep learning algorithm for solving high-dimensional PDEs; the methods/ideas in the paper have become the basis for a large amount of subsequent research in the field.

6. "Global Convergence of Deep Galerkin and PINNs Methods for Solving Partial Differential Equations". D. Jiang, J. Sirignano, and S. Cohen.
   SIAM Journal on Financial Mathematics, 17 (2), 620-645, 2026.

7. "Global Convergence of Adjoint-Optimized Neural PDEs." K. Riedl, J. Sirignano, and K. Spiliopoulos.
   Journal of Machine Learning Research, 2025.

8. $*$ "Neural Q-learning for solving Elliptic PDEs." S. Cohen, D. Jiang, and J. Sirignano.
   Journal of Machine Learning Research, 2023.
   Contribution: Neural network algorithms are being widely-used in practice for numerically solving PDEs. This is the first paper to rigorously prove convergence of a neural network algorithm trained with gradient descent to the solution of the PDE.

9. $*$ "Deep Learning Closure Models for Large-Eddy Simulation of Flows around Bluff Bodies." J. Sirignano and J. MacArt.
   Journal of Fluid Mechanics, 966 (A26), 2023.
   Contribution: This paper developed an accurate deep learning closure model for large-eddy simulation which outperformed existing closure models in the literature.

10. "PDE-constrained Models with Neural Network Terms: Optimization and Global Convergence." J. Sirignano, J. MacArt, and K. Spiliopoulos.
    Journal of Computational Physics, Vol. 481, 2023.

11. "Online Adjoint Methods for Optimization of Partial Differential Equations." J. Sirignano and K. Spiliopoulos.
    Applied Mathematics and Optimization, 85 (2), 2022.

12. "Continuous-time stochastic gradient descent for optimizing over the stationary distribution of stochastic differential equations." Z. Wang and J. Sirignano.
    Mathematical Finance, 34 (2), 348-424, 2024.

13. "OGF: An Online Gradient Flow Method for Optimizing the Statistical Steady-State Time Averages of Unsteady Turbulent Flows." T. Hickling, J. MacArt, J. Sirignano, and D. Waidmann.
Journal of Computational Physics, Vol. 552, 2026.

14. ∗ "Mean Field Analysis of Deep Neural Networks." J. Sirignano and K. Spiliopoulos.
Mathematics of Operations Research, 2021.
Contribution: This paper rigorously proved a mean-field limit for a multi-layer neural network with two hidden layers. The analysis required addressing a non-trivial closure problem in the mean-field limit analysis.

15. "Online Optimisation of Machine Learning Collision Models to Accelerate Direct Molecular Simulation of Rarefied Gas Flows." N. Ball, J. MacArt, and J. Sirignano.
Journal of Computational Physics, Vol. 549, 2026.

16. "Weak Convergence Analysis of Online Neural Actor-Critic Algorithms." S. Lam, J. Sirignano, and Z. Wang, arXiv:2403.16825, 2024.
Minor Revision at *Mathematics of Operations Research*.

17. "Physics-Based Machine Learning Closures and Wall Models for Hypersonic Transition-Continuum Boundary Layer Predictions." A. Nair, N. Singh, M. Panesi, J. Sirignano, J. MacArt.
Physical Review Fluids, 11(3), 2026.

18. "Neural Actor-Critic Methods for Hamilton-Jacobi-Bellman PDEs: Asymptotic Analysis and Numerical Studies." S. Lam, J. Hebner, D. Jiang, J. Sirignano. arXiv:2507.06428, 2025.
Invited Revision at *SIAM Journal on Financial Mathematics*.

19. "Convergence Analysis of Real-time Recurrent Learning (RTRL) for a class of Recurrent Neural Networks." S. Lam, J. Sirignano, and K. Spiliopoulos. arXiv:2501.08040, 2025.
Revise and resubmit at the *Journal of Machine Learning Research*. (Revision in progress.)

20. "Machine Learning Methods for Pricing Financial Derivatives." L. Fan and J. Sirignano.
Quantitative Finance, 1-29, 2026.

21. "oRANS: Online optimisation of RANS machine learning models with embedded DNS data generation." D. Dehtyriov, J. MacArt, and J. Sirignano. arXiv:2510.02982, 2025.
Invited Revision at the *Journal of Fluid Mechanics*. (Revision in progress.)

22. "Dynamic Deep Learning LES Closures: Online Optimization With Embedded DNS." J. Sirignano and J. MacArt. arXiv: 2303.02338, 2023.

23. ∗ "Deep Learning Closure of the Navier–Stokes Equations for Transition-Continuum Flows." A. Nair, J. Sirignano, M. Panesi, and J. MacArt.
AIAA Journal, 61 (12), pp. 5484-5497, 2023.
Selected by the AIAA Journal Editors and AIAA Journal Seminar Series Committee for an author seminar.

24. "A Forward Propagation Algorithm for Online Optimization of Nonlinear Stochastic Differential Equations." Z. Wang and J. Sirignano. arXiv:2207.04496, 2022.

25. "Global Convergence of the ODE Limit for Online Actor-Critic Algorithms in Reinforcement Learning." Z. Wang and J. Sirignano. arXiv:2108.08655, 2021
Invited Revision at *Stochastic Systems*. (Revision in progress.)

26. "Asymptotics of Reinforcement Learning with Neural Networks." J. Sirignano and K. Spiliopoulos.
Stochastic Systems, 2021.

27. "Deep Learning for Mortgage Risk." A. Sadhwani, K. Giesecke, and J. Sirignano.
Journal of Financial Econometrics, 19 (2), 2021.

28. "Embedded training of neural-network sub-grid-scale turbulence models." J. MacArt, J. Sirignano, and J. Freund.
Physical Review of Fluids, 6 (5), 2021.

29. "Stochastic Gradient Descent in Continuous Time: A Central Limit Theorem." J. Sirignano and K. Spiliopoulos.
Stochastic Systems, 10 (2), 2020.

30. "Inference for Large Financial Systems." K. Giesecke, G. Schwenkler, and J. Sirignano.
Mathematical Finance, 30 (1), 3-46, 2020.

31. "DPM: A deep learning PDE augmentation method with application to large-eddy simulation." J. Sirignano, J. MacArt, and J. Freund.
Journal of Computational Physics, 423, 2020.

32. "Universal Price Formation in Financial Markets: Insights from Deep Learning." J. Sirignano and R. Cont.
Quantitative Finance, 19 (9), 2019.

33. "Large-scale Loan Portfolio Selection." J. Sirignano, G. Tsoukalas, and K. Giesecke.
Operations Research, 64 (6), 1239-1255, 2019.

34. "Deep Learning for Limit Order Books." J. Sirignano.
Quantitative Finance, 19 (4), 2019.

35. "Risk Analysis for Large Pools of Loans." J. Sirignano and K. Giesecke. Winner of the inaugural SIAM Financial Mathematics & Engineering Conference Paper Prize.
Management Science, 65 (1), 107-121, 2018.

36. "Deep Learning-based Algebraic Reynolds Stress Closures for RANS Simulations of Turbulent Flows." D. Dehtyriov, J. MacArt, and J. Sirignano. arXiv:2605.26358, 2026.

37. "Convergence Analysis of Newton's Method for Neural Networks in the Overparameterized Limit." K. Riedl, K. Spiliopoulos, and J. Sirignano. arXiv:2605.08352, 2026.

38. "Deep Hilbert–Galerkin Methods for Infinite-Dimensional PDEs and Optimal Control." S. Cohen, F. de Feo, J. Hebner, and J. Sirignano. arXiv:2603.19463, 2026.

39. $*$ "Stochastic Gradient Descent in Continuous Time." J. Sirignano and K. Spiliopoulos.
SIAM Journal on Financial Mathematics, 8(1), 933-961, 2017.
Contribution: This paper rigorously proved convergence for continuous-time stochastic gradient descent algorithms; the mathematical techniques developed in the paper have been the foundation for research on continuous-time statistical learning in a number of subsequent publications.

40. "Large Portfolio Asymptotics for Loss from Default." K. Giesecke, K. Spiliopoulos, R. Sowers, and J. Sirignano.
Mathematical Finance, 25 (1), 77-114, 2015.

Books

- "Mathematical Foundations of Deep Learning Models and Algorithms". K. Spiliopoulos, R. Sowers, and J. Sirignano. *American Mathematical Society*, 2025.

Grants and Funding

- U.S. Office of Naval Research grant (approx. $984,000 total, $382,000 for Oxford). I am the PI for the Oxford part of this multi-university grant. Funds a four year DPhil student at Oxford. Dates: June 1, 2022 - May 31, 2026.
- NSF-EPSRC grant (£354,523 for Oxford). I am the PI for the UK part of this grant. Funds a three-year postdoctoral researcher at Oxford. Dates: March 1, 2023 - February 28, 2026.
- NSF DMS-EPSRC grant (£389,812 for Oxford). I am the PI for the UK part of this grant. Funds a three-year postdoctoral researcher at Oxford. Awarded on August 14, 2023. Anticipated dates of grant duration once postdoctoral researcher is appointed: August 1, 2024 - July 31, 2026.
- EPSRC AI Hub on the Mathematical and Computational Foundations of AI (multi-university grant for approx. £8.5 million, Co-Investigator).
- Co-PI (2020-2021) on $16.5 million DoE/NNSA PSAAP III Center. I left my role in the Center due to joining the Univ. of Oxford.
- Host PI for Schmidt AI in Science Fellowship (2024-2027). Funds a three year postdoctoral research fellowship.
- Funding for two (four year) DPhil student positions from GCHQ (approx. £522,000, co-supervised with Sam Cohen, 2024-2028).
- Funding for two postdoctoral researchers and two (four year) DPhil student positions from Squarepoint Foundation (approx. $800,000).

Industry Funding for DPhil Students

- HSBC – funding for a four-year DPhil studentship
- G-Research – funding for a four-year DPhil studentship (co-supervised with Christoph Reisinger)

Computational Allocations

- 8 million GPU hours on Frontier from the DoE's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program (2025, PI: J. MacArt, Co-PIs: J. Sirignano, T. Hickling, D. Dehtyriov)
- $160,000$ GPU hours on the EPSRC HPC facility Baskerville (2024; PI: J. Sirignano, Co-PIs: J. MacArt, T. Hickling)
- 1.5 million GPU hours from the U.S. Department of Energy (DoE) SummitPLUS program (2024, PI: J. MacArt, Co-PIs: J. Sirignano, T. Hickling)
- EPRSC HPC allocation: 160,000 GPU hours on the Baskerville HPC system (January 4, 2024 - December 31, 2024, PI: J. Sirignano, Co-PIs: J. MacArt, T. Hickling)
- 3 million GPU hours from the DoE's INCITE program (2023, PI: J. MacArt, Co-PI: J. Sirignano)

- 120,000 GPU hours on the Summit national supercomputer (2020-2021)
- 44 million core hours on the Blue Waters national supercomputer (2016-2021).

Teaching

1. Recently wrote a book "Mathematical Foundations of Deep Learning Models and Algorithms" with K. Spiliopoulos and R. Sowers, published by the American Mathematical Society (2025).
2. "Deep Learning" (2021-2026) at the University of Oxford. Mathematical theory and applications.
3. Supervision of $3-4$ MSc dissertations per year at the University of Oxford.
4. "Numerical Methods" in computational finance (2020) at the University of Oxford.
5. University of Illinois: "Deep Learning" (Fall 2016, 2017, 2018, 2019). Graduate course, cross-listed between Industrial Engineering and Computer Science. 200 graduate students (PhD and Masters) enrolled in Fall 2019 from Computer Science, Electrical Engineering, Industrial Engineering, Mechanical Engineering, and Mathematics.
    - The course had a large amount of computational resources (100,000 GPU node hours). To obtain these resources, I wrote a proposal to the Blue Waters national supercomputer for an educational grant. This large amount of computational resources made this class unique among machine learning courses, providing an excellent opportunity for students to develop deep learning models.
6. University of Illinois: "Deep Learning" (Spring 2018, 2019). Undergraduate course.
7. University of Illinois: "Deep Learning II" (Spring 2018). Graduate course.
8. University of Illinois: "Analysis of Data" (Spring 2017, Spring 2018). Undergraduate course.
9. "Machine Learning" (Spring 2016, Imperial College London, Dept. of Mathematics). Graduate course.

University Administration and Service

- Faculty member of the Center for Doctoral Training (CDT) in Mathematics of Random Systems at the University of Oxford.
- Course Director of the MSc programme in Mathematical & Computational Finance at the University of Oxford
    - In 2025, for the first time, our programme was ranked as the #1 Financial Mathematics/Quantitative Finance MSc programme in the UK.
    - Implemented changes leading to an over 200% increase in the number of applications.
    - MSc programme has expanded from ~ 35 students to 60 students.
    - Co-organized an internship programme for students with banks, investment companies, and hedge funds. The quantitative research conducted during the internship is part of the students' MSc dissertations.
    - Organized the "Careers in Quantitative Finance" seminar series where companies present internship and job opportunities to the students. Participants have included J.P. Morgan, Nomura, Deutsche Bank, Citibank, EDF Trading, Mazars, NatWest Markets (formerly Royal Bank of Scotland), QRT, Cubist Systematic, and Lloyds Bank.

- Developed and taught a new course on deep learning.
- Obtained GPU computing resources for the MSc programme and introduced high-performance computing.
- Re-designed Python course to focus on modern data science.
- Introducing new courses on cryptocurrency and blockchain, machine learning, and commodities/foreign exchange.
- Organized a new Advisory Board to establish better connections with industry.
- Obtained a small endowment (£2,500) from MUFG Securities to fund an MSc Best Thesis Prize.
- Successfully nominated students for the Natixis Prize for the Best Thesis for mathematical finance MSc programmes in Europe (Oxford received the prize in both 2021 and 2022).
- Collaborated with faculty and academic staff to obtain scholarship funds (£100,000) for the MSc Class of 2025. This has been subsequently renewed by the funder for 2026 and 2027.
- Collaborated with faculty and academic staff to obtain a Sparck AI scholarship (£44,000) for our MSc programme.
- Collaborated with faculty and academic staff to develop a new Industry Engagement Officer position for the department.

Professional Service

1. A Stream Organizer (approx. 20 sessions) for the 26th International Symposium on Mathematical Programming organized by the Mathematical Optimization Society (MOS) in Amsterdam, The Netherlands, 2027.
2. Invited to be on the Editorial Board of a new journal "Machine Learning for Modeling and Simulation in Engineering & the Sciences".
3. Associate Editor, *Mathematical Finance*.
4. Managing Editor, *Quantitative Finance*.

Career Placement of PhD students and Postdoctoral Researchers

- Tom Hickling: Lecturer (permanent position – equivalent of USA tenure-track), University of Bristol
- Lei Fan: J.P. Morgan, Systematic Trading
- Deqing Jiang: Bank of America, Fixed Income
- Ziheng Wang: Morgan Stanley, Electronic Market Making

Selected Presentations

1. Byrne Workshop on Stochastic Analysis for Finance, University of Michigan Mathematics, June 2026. Plenary Speaker.
2. California Institute of Technology, Dept. of Computing & Mathematical Sciences, April 2026. Invited Seminar.
3. Invited Seminar at Two Sigma Investments, April 2026.

4. UK AI for Turbulence Workshop, British Library, London, January 2026. Invited presentation.
5. CFM-Imperial Conference on Market Microstructure hosted by UBS in December, 2025.
6. Banff workshop "Efficient and Reliable Deep Learning Methods and their Scientific Applications", July 2025. Invited Speaker.
7. University of Waterloo, Dept. of Applied Mathematics, 2025. Invited Seminar.
8. PSU-Purdue-UMD Joint Seminar on Mathematical Data Science, 2025.
9. UCLA, Dept. of Mathematics, January 2024. Invited Seminar.
10. Invited Presentation at the 4th ACM International Conference on AI in Finance, November 2023.
11. Seminar at Imperial College London, Dept. of Mathematics, Fall 2022.
12. Seminar at the Oxford Thermofluids Institute, Fall 2022.
13. Oxford-Princeton Workshop on Stochastic Analysis and Mathematical Finance, Fall 2022.
14. Two Sigma Investments, April 2022. Invited Speaker.
15. Google Deepmind, January 2022. Invited Seminar.
16. London Business School, December 2021. Invited Seminar.
17. Brown University, Dept. of Applied Mathematics, November 2021. Invited Seminar.
18. Workshop on Deep Learning and Partial Differential Equations, Isaac Newton Institute at the University of Cambridge, November 2021. Invited Presentation.
19. Workshop on Mean-field Reinforcement Learning hosted by King's College London and Université de Paris, 2021. Invited Presentation.
20. Workshop on Deep Learning and Partial Differential Equations, Isaac Newton Institute at the University of Cambridge, November 2021. Invited Presentation.
21. Symposium on Model Consistent Data Driven Turbulence Modeling, June 2021. Invited Speaker.
22. SIAM Annual Meeting, 2021. Minisymposium organizer and presenter.
23. SIAM Conference on Financial Mathematics & Engineering, June 2021. Invited Presentation.
24. SIAM Conference on Applications of Dynamical Systems, June 2021. Invited Presentation.
25. UCLA, Dept. of Mathematics, February 2021. Invited Seminar.
26. Maven Securities, October 2020. Invited Presentation.
27. NSF Workshop on *Machine Learning in Transport Phenomena* in Dallas, Texas, February 2020. Distinguished Speaker.
28. Two Sigma Investments, New York City, January 2020. Invited Seminar.
29. University of Michigan, Dept. of Mathematics, October 2019. Invited Seminar.

30. Colloquium at UCLA, Dept. of Mathematics, May 2019.

31. Workshop on Machine Learning at the University of Toronto, Fields Institute, September 2019. Invited Speaker.

32. Carnegie Mellon University, Dept. of Statistics, January 2019. Invited Seminar.

33. Columbia University, Dept. of Industrial Engineering & Operations Research, February 2019. Invited Seminar.

34. SIAM Financial Mathematics conference, June 2019.

35. SIAM Annual Meeting, July 2018.

36. London Quantitative Finance Seminar, May 2018.

37. Princeton University, Dept. of Operations Research and Financial Engineering, 2017. Invited Seminar.

38. INFORMS Applied Probability Society Conference, Northwestern University, July 2017. Invited Presentation.

39. Northwestern University, April 2017. Invited Seminar.

40. J.P. Morgan, New York City, August 2017. Invited Seminar.

41. SIAM Financial Mathematics Conference, Austin, Texas, November 2016. Co-organized minisymposium on machine learning in finance.

42. Bank of England, London, May 2016. Invited Seminar.

43. INFORMS Annual Meeting, Nashville, November 2016. Invited Presentation.

44. London Business School, London, June 2016. Invited Seminar.

45. London-Paris Bachelier Workshop on Mathematical Finance, London, September 2015. Invited Speaker.

46. SIAM Financial Mathematics and Engineering Meeting, Chicago, 2014. Invited Speaker.

47. INFORMS Annual Meeting, San Francisco, 2014. Invited Speaker.

48. Joint Mathematics Meeting, Baltimore, 2014. Invited Speaker.

49. INFORMS Annual Meeting, Phoenix, October, 2012. Invited Speaker.

50. SIAM Financial Mathematics and Engineering Meeting, Minneapolis, 2012. Chair of the *Credit Risk* session.

51. Annual Meeting of the Canadian Applied and Industrial Mathematics Society, Toronto, 2012. Invited Speaker.

52. 5th Financial Risks International Forum, Paris, France, 2012.

Citizenship

U.S. citizen