Zachary G. Nicolaou

Washington Research Foundation Postdoctoral Fellow
Department of Applied Mathematics
University of Washington

https://znicolaou.github.io
zgn@uw.edu
(626) 716-1664

Research interests

My research focuses on the emergence of complexity, with particular emphasis on synchronization and pattern formation in networks, condensed matter, and fluid mechanical systems. I utilize classical tools from applied mathematics and novel machine learning (ML) approaches to discover and characterize mechanisms behind complex phenomena. Current topics of interest are ML-enabled system identification and reduced order modeling, symmetry concepts (including chimera states, dimension reduction methods, and converse symmetry breaking), band-gap design and associated complex phenomena such as localized states and anharmonic responses, and the kinetics of granular materials and topological defects.

Education and employment

University of Washington	Seattle, WA
Department of Applied Mathematics	04/2021-
Acting Instructor & Washington Research Foundation Postdoctoral Fellow	
University of Massachusetts Boston	Boston, MA
Postdoctoral researcher with Jason R. Green (continuation of NW work)	09/2020-02/2021
Northwestern University	Evanston, IL
Postdoctoral researcher with Adilson E. Motter	10/2016-08/2020
California Institute of Technology	Pasadena, CA
Doctor of philosophy in Physics	09/2011-06/2017
Dissertation: Symmetry and variational analyses of fluid interface equations in the thin film limit	
Advisor: Sandra M. Troian, Department of Applied Physics	
University of Cambridge	Cambridge, UK
Master of Advanced Study (Part III), Department of Applied Mathematics and Theoretical Physics Graduated, graduated with merit	10/2010-07/2011
Northwestern University	Evanston, IL
Bachelor of Arts in Physics, Mathematics, and the Integrated Science Program, GPA: 3.83/4.0	09/2006-06/2010
A01/ISP101 Programming Instructor, 2009-10	
Undergraduate Research Assistant, 2008-2010	
A01/ISP101 Programming Tutor, 2008-09	

Honors and awards

- Washington Research Foundation Postdoctoral Fellowship award, 2021-2024.
- First place, 2019 Scientific Images Contest, Northwestern Science in Society, 2019.
- Finalist in the GSNP student speaker award at the 2016 APS March Meeting, 2016.
- National Science Foundation Graduate Research Fellowship Program, 2010-13.
- Graduated with Merit, University of Cambridge Part III Mathematics, 2011.
- Outstanding Senior Thesis in Physics and Astronomy, Northwestern University, 2010.
- Undergraduate Research Internship (academic year), Northwestern University MRSEC, 2008-10.
- Summer Research Grant, Northwestern University, Summer, 2009.
- Barry M. Goldwater Scholarship, 2009.
- Katherine L. Krieghbaum Scholarship, Northwestern University, 2009.
- Phi Beta Kappa Honor Society (inducted as Junior), 2009.
- Sigma Pi Sigma Physics Honor Society (inducted as Junior), 2009.
- Best Junior in Physics, Northwestern University Physics Department, 2009.
- Outstanding Achievement in Mathematics by a Junior, Northwestern University Mathematics Department, 2009.

Scientific publications

[1] **Z. G. Nicolaou** and J. J. Bramburger, Complex localization mechanisms in networks of coupled oscillators: two case studies, arXiv preprint arXiv:2309.08547 (2023).

[2] **Z. G.Nicolaou**, When Patterns Come to Life, Comment on "Unified representation of Life's basic properties by a 3-species Stochastic Cubic Autocatalytic Reaction-Diffusion system of equations," Phys. Life Rev., in press (2023).

[3] **Z. G. Nicolaou**, G. Guo, Y. Chen, S. L. Brunton, and J. N. Kutz, Data-driven discovery and extrapolation of parameterized pattern-forming dynamics, Phys. Rev. Research, in press (2023).

[4] **Z. G. Nicolaou**, S. B. Nicholson, A. E. Motter, and J. R. Green, Prevalence of multistability and nonstationarity in driven chemical networks, J. of Chem. Phys. **158**, 225101 (2023).

[5] A. A. Kaptanoglu, B. M. de Silva, U. Fasel, K. Kaheman, A. J. Goldschmidt, J. Callaham, C. B. Delahunt, **Z. G. Nicolaou**, K. Champion, J-C. Loiseau, J. N. Kutz, and S. L. Brunton, PySINDy: A comprehensive Python package for robust sparse system identification, J. Open Source Softw. 7, 3994 (2022).

[6] A. A. Kaptanoglu, L. Zhang, **Z. G. Nicolaou**, U. Fasel, and S. L.Brunton, Benchmarking sparse system identification with low-dimensional chaos, Nonlinear Dyn. **111**, 13143–13164 (2023).

[7] **Z. G. Nicolaou**, D. Case, E. B. van der Wee, M. M. Driscoll, and A. E. Motter, Heterogeneity-stabilized homogeneous states in driven media, Nat. Commun. 12, 4486 (2021).

[8] **Z. G. Nicolaou** and A. E. Motter, Anharmonic classical time crystals, Phys. Rev. Research 3, 023106 (2021).

[9] **Z. G. Nicolaou**, M. Sebek, I. Z. Kiss, and A. E. Motter, Coherent dynamics induced by uncorrelated noise, Phys. Rev. Lett. 125, 094101 (2020).

[10] **Z. G. Nicolaou**, T. Nishikawa, S. B. Nicholson, J. R. Green, and A. E. Motter, Non-normality and non-monotonic dynamics in complex reaction networks, Phys. Rev. Research 2, 043059 (2020).

[11] **Z. G. Nicolaou**, and A. E. Motter, Missing links as a source of variable constants in complex networks, Phys. Rev. Research 2, 043135(2020).

[12] Y. Zhang, **Z. G. Nicolaou**, J. D. Hart, R. Roy, and A. E. Motter, Critical Switching Behavior in Globally Attractive Chimeras, Phys. Rev. X 10, 011044 (2020).

[13] **Z. G. Nicolaou**, D. Eroglu, and A. E. Motter, Multifaceted dynamics of Janus oscillator networks, Phys. Rev. X 9, 011017 (2019).

[14] **Z. G. Nicolaou**, B. Xu, & Adilson E. Motter, Minimal scattering entanglement in one- dimensional trapped gases, Phys. Rev. A 99, 012316 (2019).

[15] **Z. G. Nicolaou**, Stability and instability of axisymmetric droplets in thermocapillary-driven thin films, Nonlinearity 31, 1009 (2018).

[16] **Z. G. Nicolaou**, H. Riecke, & A. E. Motter, Chimera States in Continuous Media: Existence and Distinctness, Phys. Rev. Lett. 119, 244101 (2017).

[17] **Z. G. Nicolaou**, Symmetry and variational analyses of thin film partial differential equations, Caltech dissertation (2016).

[18] **Z. G. Nicolaou** and A. E. Motter, Longitudinal inverted compressibility in super-strained metamaterials, J. Stat. Phys. 151, 1162 (2013).

[19] **Z. G. Nicolaou** and A. E. Motter, Mechanical metamaterials with negative compressibility transitions, Nature Materials 11, 608 (2012).

Technical skills

- Analytic approaches
  - Symmetry analysis, dimension reduction, Lyapunov functions, and variational methods
  - Linear stability analysis, asymptotic and perturbative approaches, and bifurcation analysis
- Numerical approaches
  - Programming in Python, C, C++, Mathematica, Matlab
  - Open source developer (PySINDy github repository)
  - PDE/ODE integration with finite elements, finite differences, and (pseudo)spectral and collocation methods
  - Parallelization with OpenMP, BLAS optimization, CUDA, and Bash scripting with Slurm

Conference organization and peer review

- NetSci-X 2024 program committee member, Venice, Italy 2024.
- Physics-Informed Machine Learning seminar series organizer, University of Washington AI Institute in Dynamic Systems, Seattle 2021.
- NetSci 2020 program committee member, Rome, Italy 2020.
- NetSci-X 2020 program committee member, Tokyo, Japan 2020.
- International School and Conference on Network Science 2018, program committee member, Paris 2018.
- 9th International Conference on Complex Networks, program committee member, New England Complex Systems Institute, 2018.
- APS March Meeting 2018, focus session organizer (Session V47), Los Angeles, 2018.
- Network Frontier Workshop, organizing committee and emcee, Northwestern University, 2017.
- Reviewer for physics journals: Nature Materials, Phys. Rev. Lett., Phys. Rev. B, Phys. Rev. E, Phys. Rev. Research, Physica A: Statistical Mechanics and its Applications.
- Reviewer for mathematics journals: Nonlinearity, Chaos, Communications in Nonlinear Science and Numerical Simulation, Complex Networks, Nonlinear Science.

- Reviewer for engineering journals: ACS Nano, Mechanical Systems and Signal Processing, Sustainability.

Seminars and selected invited presentations

- Data-driven discovery and extrapolation of parameterized pattern-forming dynamics (invited minisymposium talk) SIAM Pacific Northwest Section Conference, Bellingham, WA (October 2023).
- Data-driven band gap and bifurcation design in heterogeneous driven systems, 2023 Gordon Research Conference on Collective Behavior, Newry, ME (August 2023).
- Data-driven discovery and extrapolation of parameterized pattern-forming dynamics (invited special session talk) AMS Western Sectional Meeting, University of Utah (October 2022).
- Data-driven discovery of parameterized pattern-forming dynamics and emergent quantum mechanics (invited Physical Mathematics Seminar talk), MIT Department of Mathematics (September 2022).
- Diverse effects of noise in oscillator networks (invited minisymposium talk) SIAM Conference on Applications of Dynamical Systems (May 2021).
- Diverse effects of noise in oscillator networks (invited Faculty Seminar talk). Kadir Has University, Turkey (November 2020).
- Critical switching behavior in globally attractive chimeras (invited Sydney Dynamics Group Seminar talk), University of Sydney (May 2020).
- Symmetry and asymmetry in oscillatory patterns (invited LANS Informal Seminar talk), Argonne National Laboratory (September 2019).
- Multifaceted dynamics of Janus oscillator networks (invited minisymposium talk). SIAM Conference on Applications of Dynamical Systems (May 2019).
- Computational physics inspires new insights in nature and technology (invited Physics Seminar talk), Physics Department at University of Wisconsin Whitewater (September 2018).
- Chimera states in continuous media (invited conference presentation). Topical Problems in Nonlinear Wave Physics, Moscow-St. Petersburg, Russia (July 2017).

Mentoring, teaching, and outreach

- Student and research mentor at Northwestern and University of Washington
  - University of Washington undergraduate students Xinyue Zhang & Xiyi Wang, Experimental Faraday Apparatus, Data Collection, and Processing (ongoing research, with funded AI Institute summer position for Xiyi Wang).
  - University of Washington undergraduate students Benjamin Jiang & Qichen Xu, System identification with Nonlocal Interactions for Granular Materials (ongoing research, with funded AI Institute summer position for Qichen Xu).
  - University of Washington undergraduate students Yihui Chen & Guanyu Huo, Viscid Faraday Numerics and Parametric System Identification (manuscript in preparation).
  - University of Washington graduate student Joseph Williams; System Identification for Vortex Shedding and Driven Granular Material Experiments (ongoing research).
  - University of Washington visiting scholar Pauline Brumm (TU Darmstadt); System Identification for Gravure Printing (ongoing research).
  - Northwesetern undergraduate student Fiona Brady; application material review (now graduate student at Princeton University).

- o Northwesetern graduate student Daniel J. Case; Faraday Wave instabilities (published in Nat. Comm. 2021).
  - o Northwesetern graduate student Yuanzhao Zhang; Critical Switching Chimera States (published in Phys. Rev. X 2020).
  - o Northwesetern undergraduate student Bohan Xu in quantum decoherence (published in Phys. Rev. A 2019).
- Member of the University of Washington Department of Applied Mathematics Diversity, Equity, and Inclusion Committee
  - o Organizer for the Women in Applied Mathematics Mentorship (WAMM) Program, matching graduate women mentors with undergraduate mentees.
  - o Organizer for the Pre-Application Review (PAR) program, offering graduate school application review to prospective undergraduates from underrepresented groups.
  - o Organizer and presenter for the annual Departmental Climate Orientation and Climate Check-In events, laying out expectations and resources to current and incoming graduate students and soliciting student input to guide the committee activities.
  - o Organizer for the annual Winter Diversity, Equity, and Inclusion Week, hosting educational presentations and social events highlighting cultural diversity in the department.
- Co-founder (with Sarah Wellons) of postdoc mentoring program at Northwestern
  - o Organized ice cream social events to introduce postdocs and students.
  - o Matched 15 Physics and Astronomy grad students with postdocs from other groups.
- Teaching assistant at Caltech with excellent reviews (4.7/5 for overall teaching effectiveness among 22 evaluations in 5 courses)
  - o "Zac is a fantastic TA, and was always available to answer questions about the problem set, the course, or physics in general. He has a broad base of knowledge and never hesitates to explain things in ways deeper than you might have first imagined."
  - o "Zach was an excellent TA. He was always willing to talk about the homework and class material when he was in his office (which was most of the morning and afternoon), and he was very knowledgeable about the subject. He definitely put in quite a bit more time than most other TA's will spend on classes. He was also quite approachable, which is always refreshing."
  - o "Zach was not only extremely helpful outside of class, but also in lecture as he would interject to clarify points or answer students' questions with infallibly perceptive and insightful comments. His office hours were 'by appointment,' which effectively meant 'any time–day or night'. He is a genuinely nice person and always seemed happy to help, no matter how long it took."
- Volunteer tutoring with special needs students in Caltech Y Rise program Two hours per week for one year in high school physics and chemistry.