

Zachary G. Nicolaou

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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, 04/01/2021–

Acting Instructor, Department of Applied Mathematics
Washington Research Foundation Postdoctoral Fellow

University of Massachusetts Boston, 09/01/2020–02/28/2021

Postdoctoral researcher in the group of Jason R. Green

Northwestern University, 10/01/2016–07/31/2020

Postdoctoral researcher in the group of Adilson E. Motter

California Institute of Technology, 2011-2017

Doctor of philosophy in Physics, conferred July 2017

Dissertation: Symmetry and variational analyses of fluid interface equations in the thin film limit

Advisor: Professor Sandra M. Troian

Graduate Teaching and Research Assistant, Department of Physics and Department of Applied Physics, 2013-2016

University of Cambridge, 2010-11

Master's of Advanced Study in Applied Mathematics and Theoretical Physics

Graduated with Merit, 2011

Northwestern University, 2006-10

Bachelor's of Arts in Physics, Mathematics, and the Integrated Science Program

GPA: 3.83/4.0

Programming Instructor. Northwestern Integrated Science Program A01/ISP101 Computer Programming, 2009-10

Undergraduate Research, Professor Adilson E. Motter, Department of Physics, 2008-2010

Programming Tutor. Northwestern Integrated Science Program A01/ISP101 Computer Programming, 2008-09

Honors and awards

Washington Research Foundation Postdoctoral Fellowship award, 2021-2024.

First place, 2019 Scientific Images Contest, Northwestern Science in Society, 2019.

Full membership in Sigma Xi, 2019.

Finalist in the GSNP student speaker award at the 2016 APS March Meeting, 2016.

National Science Foundation Graduate Research Fellowship Program, 2010-13.

University of Cambridge Part III Mathematics graduate with Merit, 2011.

Outstanding Senior Thesis in Physics and Astronomy, Northwestern University, 2010.

Undergraduate Research Internship, Northwestern University Materials Research Science and Engineering Center, 2008-09 and 2009-10.

Summer Research Grant, Northwestern University, Summer, 2009.

Barry M. Goldwater Scholarship, 2009.

Katherine L. Kriehbaum 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, S. B. Nicholson, T. Nishikawa, A. E. Motter, and J. R. Green, Prevalence of multistability and nonstationarity in driven chemical networks, in preparation.
- [2] Z. G. Nicolaou, G. Guo, Y. Chen, S. L. Brunton, and J. N. Kutz, Data-driven discovery and extrapolation of parameterized pattern-forming dynamics, in preparation.
- [3] A. A. Kaptanoglu, B. M. de Silva, U. Fasel, K. Kaheman, A. J. Goldschmidt, J. Callahan, C. B. Delahunt, 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).
- [4] 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).
- [5] Z. G. Nicolaou and A. E. Motter, Anharmonic classical time crystals, *Phys. Rev. Research* **3**, 023106 (2021).
- [6] Z. G. Nicolaou, M. Sebek, I. Z. Kiss, and A. E. Motter, Coherent dynamics induced by uncorrelated noise, *Phys. Rev. Lett.* **125**, 094101 (2020).
- [7] 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).
- [8] Z. G. Nicolaou, and A. E. Motter, Missing links as a source of variable constants in complex networks, *Phys. Rev. Research* **2**, 043135(2020).

- [9] 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).
- [10] Z. G. Nicolaou, D. Eroglu, and A. E. Motter, Multifaceted dynamics of Janus oscillator networks, *Phys. Rev. X* **9**, 011017 (2019).
- [11] Z. G. Nicolaou, B. Xu, & Adilson E. Motter, Minimal scattering entanglement in one-dimensional trapped gases, *Phys. Rev. A* **99**, 012316 (2019).
- [12] Z. G. Nicolaou, Stability and instability of axisymmetric droplets in thermocapillary-driven thin films, *Nonlinearity* **31**, 1009 (2018).
- [13] Z. G. Nicolaou, H. Riecke, & A. E. Motter, Chimera States in Continuous Media: Existence and Distinctness, *Phys. Rev. Lett.* **119**, 244101 (2017).
- [14] Z. G. Nicolaou, Symmetry and variational analyses of thin film partial differential equations, Caltech dissertation (2016).
- [15] Z. G. Nicolaou and A. E. Motter, Longitudinal inverted compressibility in super-strained metamaterials, *J. Stat. Phys.* **151**, 1162 (2013).
- [16] 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, and similarity solutions
 Lyapunov functions and variational methods
 Linear stability analysis, asymptotic 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 methods
 Parallelization with OpenMP, BLAS optimization, CUDA, and Bash scripting with Slurm

Conference organization and peer review

Physics-Informed Machine Learning seminar series organizer, University of Washington AI Institute in Dynamic Systems 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 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 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 Yihui Chen & Guanyu Huo, Viscid Faraday Numerics and Parametric System Identification (manuscript in preparation)

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 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)

University of Washington visiting scholar Marko Pizzoli (Sapienza University of Rome); System Identification for Gravure Printing (ongoing research)

Northwestern undergraduate student Bohan Xu in quantum decoherence (published in *Phys. Rev. A* 2019)

Northwestern graduate student Yuanzhao Zhang; Critical Switching Chimera States (published in *Phys. Rev. X* 2020)

Northwestern graduate student Daniel J. Case; Faraday Wave instabilities (published in *Nat. Comm.* 2021)

Member of the University of Washington Department of Applied Mathematics Diversity, Equity, and Inclusion Committee

Organizer for the Women in Applied Mathematics Mentorship (WAMM) Program, matching graduate women mentor with undergraduate mentees

Organizer for the Pre-Application Review (PAR) program, offering graduate school application review to prospective undergraduates from underrepresented groups

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 solicits student input to guide the committee activities

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 informal postdoc mentoring program at Northwestern

Organized ice cream social events to introduce postdocs and students

Matched 15 Physics and Astronomy grad students with postdocs from other groups

Teaching assistant at Northwestern and Caltech with excellent reviews

“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.”

“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.”

“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