

Marios Mattheakis (Matthaiakis)

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Professional Experience

- 2018– **Research Associate**, Harvard Institute for Applied Computational Science
Machine Learning, Data Science, and Applied Physics
- 2015–18 **Postdoctoral Research Fellow**, Harvard School of Engineering and Applied Sciences
Computational Materials. Advisor: Prof. Efthimios Kaxiras

Education

- 2014 **Ph.D. in Physics**, Department of Physics, University of Crete, Greece
Numerical methods for electromagnetism, nonlinear dynamical systems, stochastic flows.
Dissertation: Electromagnetic wave propagation in gradient index metamaterials, plasmonic systems and optical fiber networks. Advisor: Prof. Giorgos Tsironis
- 2012 **M. Sc., Computational Physics**, Department of Physics, University of Crete, Greece
Numerical methods for nonlinear waves in complex random networks, chaotic dynamics.
Thesis: Wave propagation in networks of Luneburg lenses. Advisor: Prof. Giorgos Tsironis
- 2010 **B. Sc., Physics**, Department of Physics, University of Crete, Greece
Thesis: Numerical Methods in Electromagnetism. Advisor: Prof. Giorgos Tsironis

Research Experience

- 2018– **Research Associate**, Harvard. Deep learning, data science, modeling
- Developed prototype physics-informed neural networks with embedded physical laws and symmetries to solve differential equations, eigenvalue, & inverse problems. Applied Transfer Learning for quick discovery of multiple accurate solutions with one-shot learning. Introduced recurrent neural network solvers based on reservoir computing. Applied these AI tools to solve the equations for nonlinear dynamical systems and to model quantum materials.
 - Designed data-driven neural networks with embedded first principles to forecast the behavior and uncover quantities (forces, energy) for dynamical systems. Improved learning by embedding integrators and use graph neural networks.
 - Developed data-driven recurrent neural networks (echo-state reservoir computing, LSTM) to forecast behavior of spatiotemporal chaotic dynamics and autonomous systems.
- 2015–18 **Postdoctoral**, Harvard. Computational materials, quantum metamaterials, applied physics
- Modeling phonon and plasmon excitations in 2D quantum materials. Developed a method for nanoscale imaging of moiré superlattices in twisted van der Waals heterostructures.
 - Designed plasmonic metamaterials with unusual properties based on 2D solids.
 - Discovered stochastic relativistic branched electronic flow in graphene & Dirac materials.
 - Manipulating light polarization with stacking of 2D black phosphorus.
 - Predicted the first visible 2D quantum plasmons in doped graphene multilayers.
- 2010–14 **Graduate Student**, University of Crete. Computational physics, photonics, random networks
- Predicted branched flow and extreme events (rogue waves) in disordered photonic media. Discovered subdiffusive nonlinear wave propagation disordered optical discrete networks.
 - Developed Finite Difference in Time Domain (FDTD) and ray-tracing algorithms to investigate metamaterials, gradient index lenses, nonlinear waves, and cloaking devices.

- Designed electromagnetic micorscale waveguides with arrangements of metamaterial lenses.
- Studied with COMSOL non-Hermitian parity-time (PT) symmetric plasmonic systems.
- Subdiffusive wave propagation in nonlinear and disordered optical discrete networks
- Participated in "MARIE-CURIE Excellence Grant entitled: **ELECTRONCOMPLEXITY**"

Teaching Experience

- 2018–21 **Instructor**, Institute of Applied Computational Science, Harvard University
 Courses: Introduction to Data Science I (CS-109a) & II (CS-109b)
- Instructed students in machine learning, data science, and deep learning.
 - Leading advanced sections, computational Labs. Prepared curriculum, lectures, exercises.
 - Supervising students on master thesis, managing research projects on machine learning.
- 2011–14 **Teaching Assistant, Department of Physics, University of Crete**
 Courses: Introduction to Programming, Labs in MATHEMATICA, and Electromagnetism
- Leading computational Labs in FORTRAN and MATHEMATICA.
 - Grading homework and exams. Held weekly office hours.

Technical Skills

Programming languages: Python, MATLAB, MATHEMATICA, Fortran, C, Java, UNIX

Computational packages: PyTorch, TensorFlow, Keras, COMSOL

Languages: Fluent in English and Greek

Invited Presentations

- Jan 2022 **Workshop on Computational Scientific Research**, Chile
 Title: *One-shot Transfer Learning of Physics-Informed Neural Networks*
- Dec 2021 **Crunch Seminar of Applied Mathematics at Brown University**, RI, USA
 Title: *One-shot Transfer Learning of Physics-Informed Neural Networks*
- Dec 2021 **Food For Thought Hour, Seminar of Applied Mathematics at Harvard University**, MA, USA
 Title: *Transfer Learning of Physics-Informed Neural Networks*
- Jul 2021 **Workshop on Machine Learning in astronomy: From classical to physics-informed**, Chile
 Title: *Physics-Informed Hamiltonian Neural Networks*
- Apr 2021 **DAiTA Labs, Universidad Mayor**, Chile
 Title: *Artificial neural networks for solving differential equations*
- Mar 2021 **Colloquium of Math at Florida State University**, Florida, USA
 Title: *Artificial neural networks for solving differential equations*
- Jan 2021 **ComputeFest 2021 at Harvard**, MA, USA
 Title: *Transfer Learning: How to use existing models for transfer learning, identify similarity in the embedding space, and distilling knowledge from pre-trained neural networks*
- Jan 2020 **ComputeFest 2020 at Harvard**, MA, USA
 Title: *How to use existing models for transfer learning*
- Nov 2019 **Colloquium of Physics at Rensselaer Polytechnic Institute**, New York, USA
 Title: *Two-dimensional materials, metamaterials & Machine Learning*
- Oct 2019 **Global Innovation Forum, Transforming Intelligence**, Yerevan, Armenia
 Title: *Machine Learning for Dynamical Systems*
- Sep 2019 **ACM International Conf. on Nanoscale Computing and Communication**, Dublin, Ireland
 Title: *Graphene epsilon-near-zero plasmonic crystals*
- Mar 2016 **Seminar of Crete Center for Quantum Complexity & Nanotechnology**, Crete, Greece
 Title: *Plasmonic periodic structures composed by 2D materials*
- Sep 2015 **Colloquium of Physics, Wesleyan University**, Connecticut, USA
 Title: *Surface plasmons in active systems and 2D materials*

Conference, Workshops, and Summer School participation

- Dec 2020 **NeurIPS Workshop on Machine Learning and Physical Sciences**, Online
Titles: (I) *Unsupervised Neural Networks for Quantum Eigenvalue Problems*;
(II) *Semi-supervised Neural Networks Solve an Inverse Problem for Modeling Covid-19 Spread*
- Mar 2019 **APS March Meeting**, Boston, Massachusetts, USA
Title: *Physical Symmetries Embedded in Neural Networks*
- Mar 2018 **APS March Meeting**, Los Angeles, California, USA
Title: *Electronic Branched Flow in Graphene: Theory and Machine Learning Prediction*
- Mar 2018 **Workshop on Theory and Computation for Transport Properties in 2D Material**, Minneapolis, Minnesota, USA
- May 2017 **Mathematical Modeling of 2D Materials**, Minneapolis, Minnesota, USA
Title: *Epsilon-Near-Zero from plasmonic Dirac point: Theory and realization using 2D materials*
- Mar 2017 **APS March Meeting**, New Orleans, Louisiana, USA
Title: *Epsilon-Near-Zero from plasmonic Dirac point: Theory and realization using 2D materials*
- Feb 2017 **Boston Photonics Centennial Conference**, Cambridge, Massachusetts, USA
Title: *Epsilon-Near-Zero from plasmonic Dirac point: Theory and realization using 2D materials*
- Jul 2016 **Nanosciences & Nanotechnologies (NN16)**, Thessaloniki, Greece
Title: *Epsilon-Near-Zero and Plasmonic Dirac Point by using 2D materials*
- Sep 2014 **COMSOL conference**, Cambridge, United Kingdom
Title: *Enhanced surface plasmon polariton propagation induced by active dielectrics*
- Jul 2014 **International Workshop on Statistical Mechanics and Dynamical Systems**, Athens, Greece
Title: *Linear and nonlinear photonic rogue waves in complex transparent media*
- Jul 2014 **Complex Systems**, Athens, Greece
Title: *Linear and nonlinear photonic rogue waves in complex transparent media*
- Jul 2014 **International Conference on Statistical Physics**, held by SigmaPhi Committee, Rhodes, Greece
Title: *Linear and nonlinear photonic rogue waves in complex transparent media*
- Mar 2014 **Dynamics Symposium**, organized by the Max Planck Institute for Dynamics and Self Organization (Goettingen) on Mandarfen in Austria
- Dec 2013 **Light in Disordered Photonic Media**, held by the Physikzentrum Bad Honnef, Germany.
Title: *Observation of photonic rogue waves in strongly scattering random media*
- Jul 2013 **Third European Ph.D. School on Mathematical Modeling of Complex Systems**, organized by the Department of Physics, University of Crete, Greece
Title: *Linear optical rogue waves in disordered photonic networks*
- Aug 2012 **International Workshop on Statistical Mechanics and Dynamical Systems**, by ITAP, Turkey
Title: *Luneburg lens waveguide networks*
- Sep 2011 **Nanoantennas and Hybrid Quantum Systems**, held by the Physikzentrum Bad Honnef, Germany
- Aug 2011 **Charged Particle Optics: Theory and Simulations (CPOT)**, organized by the Department of Physics, University of Crete, Greece
- Jul 2011 **First European Ph.D. School on Mathematical Modeling of Complex Systems**, organized by the Department of Mathematics, University of Patras, Greece

Professional Activities, Leadership, Service, and Career development

Fellowships and Awards

- 2021 Selected as the SEAS single nominee for the Harvard University-wide competition for the Aramont Fund Postdoctoral Fellowship
- 2021 Awarded as an IOP Trusted Reviewer

Reviewer for International Journals and Conferences

- Nature Communications
- Physical Review Letters
- Physical Review Research
- Nano Letters
- J. of Computational Physics
- Chaos Solitons & Fractals
- Optical Materials Express
- Optics Express
- Nanotechnology
- NeurIPS 2021
- AAAS Science Advances
- Physical Review Applied
- Physical Review B
- Applied Nano Materials
- Wave Motion
- Applied Physics Letters
- JOSA B
- Continuum
- Physica Scripta
- AISTATS 2022
- Royal Society Proceedings A
- Physical Review A
- European Phys. Journal B
- Selected Topics in Quantum Electronics
- Optical Materials
- J. of Applied Physics
- Applied Optics
- Engineering Research Express
- J. of Applied Math and Physics
- ACM NanoCom 2019-2021 conference

Memberships

- American Physical Society (APS)
- Association for Computing Machinery (ACM)

Committees/Organizational Services

- 2019–21 Technical Program Committee for ACM International Conference on Nanoscale Computing and Communication
- 2020–21 Master’s Thesis committee for CSE Master’s program at Harvard
- 2020–21 Co-organizer of Transfer Learning workshops for ComputeFest at Harvard
- 2020–21 Assisting prospective graduate students from underrepresented and/or historically minoritized communities in STEM. Harvard Graduate School Application Assistance Initiative
- 2020–22 Judging committee for the National Collegiate Research Conference
- 2021–22 Judging committee for the science competition ENVISION held by Women in STEM
- 2021 Mentoring female or nonbinary high-school students, Talaria Research Program held by ATHENA
- 2021 Co-organizer of the Data Science Pedagogy Workshop held by Harvard

Students Advisor & Mentor

- 2021– **Raphael Pellegrin**, Master student at Harvard University
- 2021– **Madison Shirazi** undergraduate student at Harvard University
- 2021– **Aidan Carey**, undergraduate student at Harvard University
- 2021– **Edward Koh**, undergraduate student at Harvard University
- 2021– **Emin Berker**, undergraduate student at Harvard University
- 2021 **John Chen**, undergraduate student at Harvard University
- 2020– **Henry Jin**, Master student at Harvard University
- 2020– **Hayden Joy**, Research Assistant at Harvard University and Rensselaer Polytechnic Institute
- 2020–21 **Anwesh Bhattacharya**, Ph.D student at Birla Institute of Technology & Science
- 2020 **Alessandro Patocchio**, Master student at Politecnico di Milano
- 2020 **Tommaso Scarlatti**, student at Politecnico di Milano
- 2019–21 **Jing Tang**, Undergraduate student at Nanjing University

References

1. **Prof. Efthimios Kaxiras**, Department of Physics and John A. Paulson School of Engineering and Applied Sciences, Harvard University
2. **Prof. Georgios Tsironis**, Department of Physics, University of Crete
3. **Dr. Pavlos Protopapas** John A. Paulson School of Engineering and Applied Sciences, Harvard University
4. **Prof. Stephen Roberts** Man Group Chair in Machine Learning, University of Oxford

Publications [Google Scholar Profile]

1. H. Jin, **M. Mattheakis**, P. Protopapas: *Physics-Informed Neural Networks for Quantum Eigenvalue Problems.*, JCNN at IEEE World Congress on Computational Intelligence (2022) [[Link](#)]
2. A. Bhattacharya, **M. Mattheakis**, P. Protopapas: *Encoding Involutory Invariance in Neural Networks*, JCNN at IEEE World Congress on Computational Intelligence (2022) [[Link](#)]
3. M. Angelia, G. Neofotistos, **M. Mattheakis**, E. Kaxiras: *Modeling the effect of the vaccination campaign on the Covid-19 pandemic*, Chaos, Solitons & Fractals **154**, 111621 (2022) [[Link](#)]
4. S. Desai, **M. Mattheakis**, S. Roberts: *Variational Integrator Graph Networks for Learning Energy Conserving Dynamical Systems*, Phys. Rev. E **104**, 035310 (2021) [[Link](#)]
5. S. Desai, **M. Mattheakis**, D. Sondak, P. Protopapas, S. Roberts: *Port-Hamiltonian Neural Networks for Learning Explicit Time-Dependent Dynamical Systems*, Phys. Rev. E **104**, 034312 (2021) [[Link](#)]
6. H. Jin, **M. Mattheakis**, P. Protopapas: *Unsupervised Neural Networks for Quantum Eigenvalue Problems*, NeurIPS Workshop on Machine Learning and Physical Sciences (2020) [[Link](#)]
7. A. Paticchio, T. Scarlatti, **M. Mattheakis**, P. Protopapas, M. Brambilla: *Semi-supervised Neural Networks solve an inverse problem for modeling Covid-19 spread*, NeurIPS Workshop on Machine Learning and Physical Sciences (2020) [[Link](#)]
8. **M. Mattheakis**: *Riding Waves in Neuromorphic Computing*, APS Physics **13**, 132 (2020) [[Link](#)]
9. Y. Luo, R. Engelke, **M. Mattheakis**, M. Tamagnone, S. Carr, K. Watanabe, T. Taniguchi, E. Kaxiras, P. Kim, and W. L. Wilson.: *In-situ nanoscale imaging of moiré superlattices in twisted van der Waals heterostructures*, Nature Communication **11**, 4209 (2020) [[Link](#)]
10. G. A. Tritsarlis, Y. Xie, A. M. Rush, S. Carr, **M. Mattheakis**, E. Kaxiras: *LAN – A materials notation for 2D layered assemblies*, J. Chem. Inf. Model., **60**, 3457-3462 (2020) [[Link](#)]
11. G. A. Tritsarlis, S. Carr, Z. Zhu, Y. Xie, S. Torrisi, J. Tang, **M. Mattheakis**, D. Larson, E. Kaxiras: *Electronic structure calculations of twisted multi-layer graphene superlattices*, 2D Materials **7**, 035028 (2020) [[Link](#)]
12. F. Chen, D. Sondak, P. Protopapas, **M. Mattheakis**, S. Liu, D. Agarwal, and M. Di Giovanni: *NeuroDiffEq: A Python package for solving differential equations with neural networks*, Journal of Open Source Software, 5(46), 1931 (2020) [[Link](#)]
13. G. Barmparis, G. Neofotistos, **M. Mattheakis**, J. Hitzanidi, G.P. Tsironis, E. Kaxiras: *Robust prediction of complex spatiotemporal states through machine learning with sparse sensing*, Phys. Let. A, **384**, 126300 (2020) [[Link](#)]
14. G. Neofotistos, **M. Mattheakis**, G. Barmparis, J. Hitzanidi, G.P. Tsironis, E. Kaxiras: *Machine learning with observers predicts complex spatiotemporal behavior*. Front. Phys. - Quantum Computing, **7**, 24 (2019) [[Link](#)]
15. M. Maier, **M. Mattheakis**, E. Kaxiras, M. Luskin, and D. Margetis: *Homogenization of plasmonic crystals: Seeking the epsilon-near-zero behavior*. Proc. R. Soc. A, **475**, 20190220 (2019) [[Link](#)]
16. **M. Mattheakis**, M. Maier, W. Xi Boo, and E. Kaxiras: *Graphene epsilon-near-zero plasmonic crystals*. Proceeding ACM Nanoscale Computing and Communication (2019) [[Link](#)]
17. **M. Mattheakis**, G. P. Tsironis, and E. Kaxiras: *Emergence and dynamical properties of stochastic branching in the electronic flows of disordered Dirac solids*. EPL **122**, 27003 (2018) [[Link](#)]
18. S. N. Shirodkar, **M. Mattheakis**, P. Cazeaux, P. Narang, M. Soljačić, E. Kaxiras: *Quantum plasmons with optical-range frequencies in doped few-layer graphene*. Phys. Rev. B **97**, 195435 (2018) [[Link](#)]
19. M. Maier, **M. Mattheakis**, E. Kaxiras, M. Luskin, and D. Margetis: *Universal behavior of dispersive Dirac cone in gradient-index plasmonic metamaterials*. Phys. Rev. B **97**, 035307 (2018) [[Link](#)]
20. N. Hassan, **M. Mattheakis**, and M. Ding: *Sensorless Node Architecture for Events Detection in Self-Powered Nanosensor Networks*. Nano Communication Networks **19**, 1-9 (2018) [[Link](#)]

21. **M. Mattheakis**, G. P. Tsironis, and E. Kaxiras: *Graphene and Active Metamaterials: Theoretical Methods and Physical Properties*, Nanoplasmonics - Fundamentals and Applications, InTech (2017) [[Link](#)]
22. C. A. Valagiannopoulos, **M. Mattheakis**, S. N. Shirodkar, and E. Kaxiras: *Manipulating polarized light with a planar slab of Black Phosphorus* J. Phys. Commum. **1**, 045003 (2017) [[Link](#)]
23. O. V. Shramkova, **M. Mattheakis**, G. P. Tsironis: *Amplification of surface plasmons in active nonlinear hyperbolic systems* Proceedings of the 47th European Microwave Conference, 488-491 (2017) [[Link](#)]
24. **M. Mattheakis**, C. A. Valagiannopoulos, and E. Kaxiras: *Epsilon-Near-Zero behavior from Plasmonic Dirac Point: theory and realization using two-dimensional materials*, Phys. Rev. B **94**, 201404(R) (2016) [[Link](#)]
25. **M. Mattheakis**, I. J. Pitsios, G. P. Tsironis, and S. Tzortzakis: *Extreme events in complex linear and nonlinear photonic media*, Chaos, Solitons & Fractals **84**, 73-80 (2016) [[Link](#)]
26. **M. Mattheakis**, T. Oikonomou, M. I. Molina, and G. P. Tsironis: *Phase transition in \mathcal{PT} symmetric active plasmonic systems*, IEEE Journal of Selected Topics in Quantum Electronics **22**, Vol.5 (2015) [[Link](#)]
27. **M. Mattheakis**, and G. P. Tsironis: *Extreme waves and branching flows in optical media*, Quodons in mica: nonlinear localized travelling excitations in crystals, Springer series in materials science, pp 425-454 (2015) [[Link](#)]
28. F. Perakis, **M. Mattheakis**, and G. P. Tsironis: *Small-world networks of optical fiber lattices*, J. Opt. **16**, 102003 (2014) [[Link](#)]
29. C. Athanasopoulos, **M. Mattheakis**, and G. P. Tsironis: *Enhanced surface plasmon polariton propagation induced by active dielectrics*, Expert from the Proceedings of the 2014 COMSOL conference in Cambridge (2014) [[Link](#)]
30. **M. Mattheakis**, G. P. Tsironis, and V. I. Kovanis: *Luneburg lens waveguide networks*, J. Opt. **14**, 114005 (2012) [[Link](#)]

Submitted/Preprints

31. **M. Mattheakis**, H. Joy, P. Protopapas: *Unsupervised Reservoir Computing for Solving Ordinary Differential Equations*, arXiv: 2108.11417 (2021, submitted) [[Link](#)]
32. S. Desai, **M. Mattheakis**, H. Joy, P. Protopapas, S. Roberts: *One-Shot Transfer Learning of Physics-Informed Neural Networks.*, arXiv: 2110.11286 (2021, submitted) [[Link](#)]
33. T. A. E. Ferreira, **M. Mattheakis**, P. Protopapas: *A New Artificial Neuron Proposal with Trainable Simultaneous Local and Global Activation Function*, arXiv: 2101.06100 (2021) [[Link](#)]
34. **M. Mattheakis**, D. Sondak, S. Dogra, P. Protopapas: *Hamiltonian neural networks for solving differential equations*, arXiv: 2001.11107 (2020, submitted) [[Link](#)]
35. **M. Mattheakis**, P. Protopapas, D. Sondak, M. Di Giovanni, E. Kaxiras: *Physical symmetries embedded in Neural Networks*, arXiv: 1904.08991 (2019) [[Link](#)]