Eslam Abdelaleem

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Research Summary

My research develops principled, information-theoretic machine learning techniques to quantify and extract meaningful representations from complex, high-dimensional data. I specialize in creating novel methods to uncover latent dynamical variables in neural recordings and other empirical systems, bridging computational neuroscience, statistical physics, and machine learning.

Appointments

2024 – Present **Postdoctoral Fellow**
Schools of Physics and Psychology, Georgia Institute of Technology
Advisor: Dr. Audrey Sederberg

2025 – 2026 **Lecturer**
Schools of Physics and Psychology, Georgia Institute of Technology
Formally appointed to co-instruct *Physics of Cognition* (Fall 2025, Spring 2026).

Education

2019 – 2024 **Ph.D. in Physics**, Emory University, Atlanta, GA
Advisor: Dr. Ilya Nemenman
Dissertation: *Simultaneous Dimensionality Reduction for Extracting Useful Representations of Large Empirical Multimodal Datasets*

2015 – 2019 **B.Sc. in Physics of Earth and Universe**, University of Science and Technology at Zewail City, Egypt
Thesis: *Monte Carlo simulations in statistical physics: Wang-Landau sampling*

Grants & Funding

2025 **CoCo Pilot Grant** ($2,000)
Center of Excellence in Computational Cognition
Project: Tracking the Trajectory of Adaptation: A Deep Learning Approach to Dynamic Functional Connectivity.
Funding supports an undergraduate researcher to deploy a deep learning-based Mutual Information Estimation framework for quantifying dynamic functional connectivity and network reorganization in high-density EEG recordings.

Publications

Peer-Reviewed Publications

[6] M. Shane Li, et al. including **Eslam Abdelaleem**. *Measurement effects on critical scaling in neural systems. Frontiers in Computational Neuroscience*, 2025.

[5] **Eslam Abdelaleem***, Ilya Nemenman, K. Michael Martini*. *Deep Variational Multivariate Information Bottleneck – A Framework for Variational Losses.* *Journal of Machine Learning Research (JMLR)*, 26(127):1-58, 2025.

[4] Wentao Yu, **Eslam Abdelaleem**, Ilya Nemenman, Justin C. Burton. *Physics-tailored machine learning reveals unexpected physics in dusty plasmas.* *PNAS*, 2025.

[3] Natalie Blot, et al. including **Eslam Abdelaleem**. *How host mobility patterns shape antigenic escape during viral-immune co-evolution.* *PRX Life*, 3(2), 2025.

[2] **Eslam Abdelaleem**, Ahmed Roman, K. Michael Martini, Ilya Nemenman. *Simultaneous Dimensionality Reduction: A Data Efficient Approach for Multimodal Representations Learning.* *Transactions on Machine Learning Research (TMLR)*, 2024.

[1] Alaa Bakry*, **Eslam Abdelaleem***, et al. *Using Eye Movement to Assess Auditory Attention.* *AMLTA*, 2019.

** Denotes equal contribution.*

Manuscripts Under Review

[1] **Eslam Abdelaleem***, K. Michael Martini*, Ilya Nemenman. *Accurate Estimation of Mutual Information in High Dimensional Data.* Under review, *ICLR 2026.*

Manuscripts in Preparation

[1] Paarth Gulati*, **Eslam Abdelaleem***, et al. *Intrinsic and Shared dimensionality estimation using mutual information in high dimensional datasets.*

[2] Benyuan Liu*, Yung-Ying Chen*, **Eslam Abdelaleem***, et al. *Power laws in empirical eigenvalue spectra.*

[3] K. Michael Martini*, **Eslam Abdelaleem***, Ilya Nemenman. *DySIB: Learning Dynamical State Variables from High-Dimensional Observations.*

[4] **Eslam Abdelaleem**, Leo Wood, K. Michael Martini, Simon Sponberg, Ilya Nemenman, Audrey Sederberg. *NeuralMI: A Toolbox for Rigorous Mutual Information Estimation in Neuroscience.*

[5] Leo Wood, **Eslam Abdelaleem**, Audrey Sederberg, Simon Sponberg. *Hawkmoth descending neurons carry motor information in spike timing across synergistic populations.*

[6] Benyuan Liu, M. Shane Li, **Eslam Abdelaleem**, Audrey Sederberg. *Replicating Scaling Laws in multiple brain regions using a Latent Variable Model of Neural Activity.*

Selected Media Coverage

- **"AI Reveals Unexpected New Physics in Dusty Plasma."** *Emory University News*, July 2025. Feature on *PNAS* 2025 paper. Covered by 21+ news outlets, podcasts, and blogs.
- **"'Periodic Table' for AI Methods Aims to Drive Innovation."** *Emory University News*, December 2025.
  Feature on *JMLR* 2025 paper (*Deep Variational Multivariate Information Bottleneck*).

Presentations

- **Invited Talk:** "Less is More (When Done Right): A Guide to Smarter Reduction." Georgia Tech School of Psychology, Brown Bag Seminar, September 2025.
- **Selected Talk:** "Simultaneous Dimensionality Reduction..." Physics of Life: Students and Postdocs Edition, CUNY, NY, Spring 2024.
- **Selected Talk:** Atlanta Biophysics Meetup, Atlanta, GA, 2023.
- **Contributed Talks:** APS March Meeting (2021, 2022, 2023, 2024, 2025); iPoLS Montpellier (2022), Champalimaud Research Symposium (2021).

Teaching

Spring 2026 — **Guest Lecturer**, Georgia Institute of Technology
PSYC 4690/6690: Neuro AI Models of the Brain and Mind
Invited by the instructor Prof. Ratan Murty to deliver a lecture on approaches of dimensionality reduction.

Fall 2025 – Spring 2026 — **Co-Instructor**, Georgia Institute of Technology
PHYS/PSYC 4745 & PSYC 6745 – Physics of Cognition
Co-teaching alongside Prof. Tansu Celikel (Chair, School of Psychology). Responsible for curriculum development, lecturing, and leading research-based student projects.

July 2024 — **Instructor**, Emory IPoLS Scientific Programming Bootcamp
Designed and delivered "A Gentle Introduction to Machine Learning" (dimensionality reduction, neural networks, variational methods).

2019 – 2024 — **Teaching Assistant**, Emory University
Labs for Introductory Physics (Mechanics, E&M, Optics) and Statistical Inference.

Mentoring Experience

- **Research Mentoring**, Sederberg Lab, Georgia Tech (2024 – Present)
  Mentored current PhD students: Benyuan Liu, Sina Dabiri, Yung-Ying Chen, and Research Scientist M. Shane Li (now PhD student at U. Cincinnati).

Professional Service

- **Reviewer:** President's Undergraduate Research Award, Georgia Tech (Spring 2026).
- **Judge:** Undergraduate Research Spring Symposium (Neuroscience Session), Georgia Tech (Spring 2025).
- **Co-founder & Lecturer:** Zewail City Physics Alumni Winter School (2025).
- **Board of Trustees Member:** Zewail City Alumni Association (2020 – Present).
- **President:** A&A Grant Initiative (2021).
- **Lead:** ZC OpenCourseWare LaTeX Team (2017 – 2019).

Awards

- Best Undergraduate Presentation Award, 4th Int'l Conf. on Advanced Machine Learning (2019).
- Zewail City Certificate for Scientific Achievements (2019).
- Provost's Honors Roll, Zewail City (2015).

References

Dr. Audrey Sederberg
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