Toni J.B. Liu

Department of Physics, Cornell University | www.toni-liu.com | jl3499@cornell.edu | Google Scholar

Education

Cornell University, Ithaca, NY — *August 2022 –*
Graduate student in Physics | *GPA*: 4.3 / 4.09 — Advisor: Prof. Chris Earls

California Institute of Technology, Pasadena, CA — *September 2019 – June 2021*
Bachelor of Science: Applied Physics | *GPA*: 3.84 / 4.3

Wesleyan University, Middletown, CT — *September 2016 – May 2019*
Bachelor of Arts: Physics Major and Film Studies Minor | *GPA*: 3.75 / 4.3

Research interests

Neural dynamics, manifold learning, information geometry, statistical mechanics of learning systems

Honors and Awards

Mong Cornell Neurotech Fellowship, Cornell — *August 2023 - August 2024*

Larson Scholarship, Caltech — *Summer 2020*

Dean's List, Wesleyan University — *Fall 2016, Fall 2017,* & *Spring 2020*

Publications

- **T. J.B. Liu**, N. Boullé, R. Sarfati, & C. J. Earls,
  Density estimation with LLMs: a geometric investigation of in-context learning trajectories, manuscript under review
- **T. J.B. Liu**, N. Boullé, R. Sarfati, & C. J. Earls,
  LLMs learn governing principles of dynamical systems, revealing an in-context neural scaling law, EMNLP (2024)
- **T. J.B. Liu**, T. Yu, A. Tseng, & C. De Sa,
  Shadow cones: a generalized framework for partial order embedding, ICLR (2024)
- R. Sarfati, **T. J.B. Liu**, N. Boullé, & C. J. Earls,
  Lines of Thought in Large Language Models, manuscript under review
- A. Tseng, T. Yu, **T. J.B. Liu**, & C. De Sa,
  Coneheads: hierarchy aware attention, NeurIPS (2023)
- E. Afik, **T. J.B. Liu**, & E. M. Meyerowitz,
  Macroscopic waves, Biological clocks, and morphogenesis driven by light in a giant unicellular green alga, Nat Commun **14**, 6204 (2023)

Selected conference presentations

- **T. J.B. Liu**, J. Z. Kim,
  Diffusion RNN: extracting low-dimensional structures in data as quasi-stable manifolds, 2024 APS March Meetin

Research

In-context learning dynamics of foundation models, SciAI Center, Cornell University *August 2023 – Present*

- Demonstrated LLaMA 2's zero-shot ability to model the evolution of dynamical systems without fine-tuning or instruction prompting
- Implemented *Hierarchy-PDF*, a computationally efficient framework to extract statistical information of dynamical systems learned by transformer-based LLMs
- Discovered an in-context neural scaling law, relating the fidelity of learned transition rules to number of states observed in-context
- Discovered "dispersive attention head", an emergent algorithm underlying various probabilistic reasoning abilities of LLMs
- Investigating the learning algorithms that transformer-based LLMs implicitly implement during inference

Diffusion RNN for dimensionality reduction, SciAI Center, Cornell University *August 2023 – Present*

- Developed diffusion RNN: a fully recurrent neural network that uses a reverse-diffusion process to extract low-dimensional structures in data as quasi-stable manifolds
- Currently investigating the memory-abstraction trade-offs in Diffusion RNN

Riemannian embedding of graphs, Relax ML Lab, Cornell University *March 2023 – Present*

- Developed "Shadow Cones": a fast framework for embedding graphs in Riemannian spaces
- Empirically demonstrated the advantages of hyperbolic space for embedding graphs with tree-like structures
- Generalizing the shadow cone framework to multi-relation graphs

Energy-based anomaly detection, Cohen Lab, Cornell University *January 2023 – July 2023*

- Developed energy-based machine learning algorithms to automatically detect and correct anomalies in reconstructed flight trajectories of insects

Light-driven morphogenesis of algae, Meyerowitz Lab, Caltech *June 2020 – January 2023*

- Studied macroscopic, self-organized organelle waves in *Caulerpa* – a single-celled alga – via computational image processing, time-series analysis, and PDE models
- Developed image registration pipelines to segment and track the growth of *Caulerpa* blades; Perform dimensionality reduction to extract intracellular activities and developmental morphology using Python's SciPy ecosystem
- Use variational auto-encoders to discover eigen-modes of intracellular fluid transports
- Model the anticipatory behavior of cellular dynamics using Kuramoto networks

Optical Characterization of Phase-change materials, Sher Lab, Wesleyan University *February 2018 – July 2019*

- Built thermo-optical simulations in COMSOL, and computationally evaluated the performance of various photonic limiters – multi-layered optical devices that provided non-linear intensity control to protect optical sensors ranging from radars to eyes
- Experimentally characterized temperature-dependent optical properties of GST and ZnO – non-linear materials crucial to the design of photonic limiters; theoretically investigated the origins of optical non-linearity: first-order phase transition and exciton quenching
- Constructed analytical models to interpret the ellipsometry data and characterized the temperature-dependent optical constants of GST and ZnO; experimentally verified the first-order phase transition in GST and exciton quenching temperature of ZnO

Teaching

Phys 2207 – Newtonian Mechanics and Fluid Mechanics, TA and lab instructor, Cornell Univ. *Fall 2022*
Phys 2208 – Electricity and Magnetism and Quantum Mechanics, TA and lab instructor, Cornell Univ. *Spring 2023*

Performing and Media Arts

Film-maker and Animator, Wesleyan Cardinal Pictures and Independent *February 2017 – Present*

- Directed 15- and 4-person crews, and created short films:
  OCD – A Love Story : a psychological thriller exploring the limits of understanding reality and the self
  Allegory of the Grotto : a film-noir interpretation of Plato's classic tale
- Both films were selected and screened at the Wesleyan Student Film Festival
- Currently developing a series of hand-drawn animations, randomly themed
  Life: a Study of Motion: the inaugural piece

Tenor, Cornell University Chorale *February 2023 – Present*

- Performing biannually, showcasing a diverse repertoire from classical masses to modern folk pieces

Skills

Programming Languages:	Python, MATLAB, Mathematica, COMSOL Multiphysics, LabView
Data analysis and Machine Learning:	Pandas, NumPy, SciPy, scikit-image, scikit-learn, PyTorch, Keras
Visual Presentation:	Adobe Photoshop, Blender, Apple Motion, Final Cut Pro
Languages:	English (fluent), Mandarin (native), Italian (working proficiency)