Math + Neuroscience:

Strengthening the interplay between theory and mathematics

Thursday, September 7, 2023
ICERM @ Brown University

Organizers: Carina Curto, Katie Morrison, Brent Doiron, Robert Ghrist, Kathryn Hess, Zack Kilpatrick, Matilde Marcolli, Konstantin Mischaikow, Tatyana Sharpee, Elad Schneidman

Overview of the semester

Week 0: Sep 6-8 (Wed-Fri) — Introductions, Planning, Welcome

Week 1: Sep 11-15

Mon-Tue: Short talks by grads and postdocs, Welcome Reception

Wed-Fri: Begin Off-workshop-week program

Week 2: Sep 18-22 — Workshop 1 (network dynamics)

Week 3: Sep 25-29 — Off-workshop-week program

Week 4: Oct 2-6 — Off-workshop-week program

Week 5: Oct 9-13 — Off-workshop-week program

Week 6: Oct 16-20 — Workshop 2 (topology and geometry)

Week 7: Oct 23-27 — Off-workshop-week program

Week 8: Oct 30-Nov 3 — Workshop 3 (neural codes)

Week 9: Nov 6-10 — Off-workshop-week program

SfN is Nov 11-15 in Washington, DC

Week 10: Nov 13-17 — Off-workshop-week program

Week 11: Nov 20-24 — Thanksgiving week, partial program

Week 12: Nov 27-Dec 1 — Off-workshop-week program

Week 13: Dec 4-8 — Final week! Presentations, wrap-up, etc.

Workshops

Week 2: Sep 18-22 — Workshop 1 (network dynamics)
Mathematical Challenges in Neuronal Network Dynamics

Week 6: Oct 16-20 — Workshop 2 (topology and geometry)
Topology and Geometry in Neuroscience

Week 8: Oct 30-Nov 3 — Workshop 3 (neural codes)
Neural Coding and Combinatorics

Off-workshop weeks

Monday	Tuesday	Wednesday	Thursday	Friday
10–11am **Journal Club**	9–10:30am **Tutorial** 11–12pm **Office Hours***	9–10am **Prof Develop. Seminar** 2–3pm **Office Hours***	9–10:30am **Tutorial** 12–1:30pm **Open Problems Lunch Seminar**	9:30–10:30am **Something Cool I Know Seminar** 11–12pm **Grad student/ Postdoc seminar** 1:30–3:00pm **Topology+Neuro Working Group**
---------- 3–3:30pm **Daily Coffee & Tea Break** ----------				
3:30–5:00pm **TLN Working Group**		3:30–4:30 **Math+Neuro Seminar**	4:00–5:00pm **Carney's Neuro Seminar**	

* **Office Hours:** Carina's in 1001 & Katie's in 1002

Open Problems Seminar

- What are the mathematical obstacles to progress in (theoretical) neuroscience?

- How do we formulate questions in neuroscience in a mathematically precise way?

Open Problems Seminar

- What are the mathematical obstacles to progress in (theoretical) neuroscience?
- How do we formulate questions in neuroscience in a mathematically precise way?
- Goal 1: to develop a list of problems, together with the relevant scientific background and context, that a mathematician could work on without first needing a deep dive into neuroscience.
- Goal 2: to promote new collaborations between neuroscientists (especially computational/theoretical neuroscientists) and mathematicians working in a wide variety of areas.
- Note: some of this may be done with the Carney Institute for Brain Science, here at Brown U.

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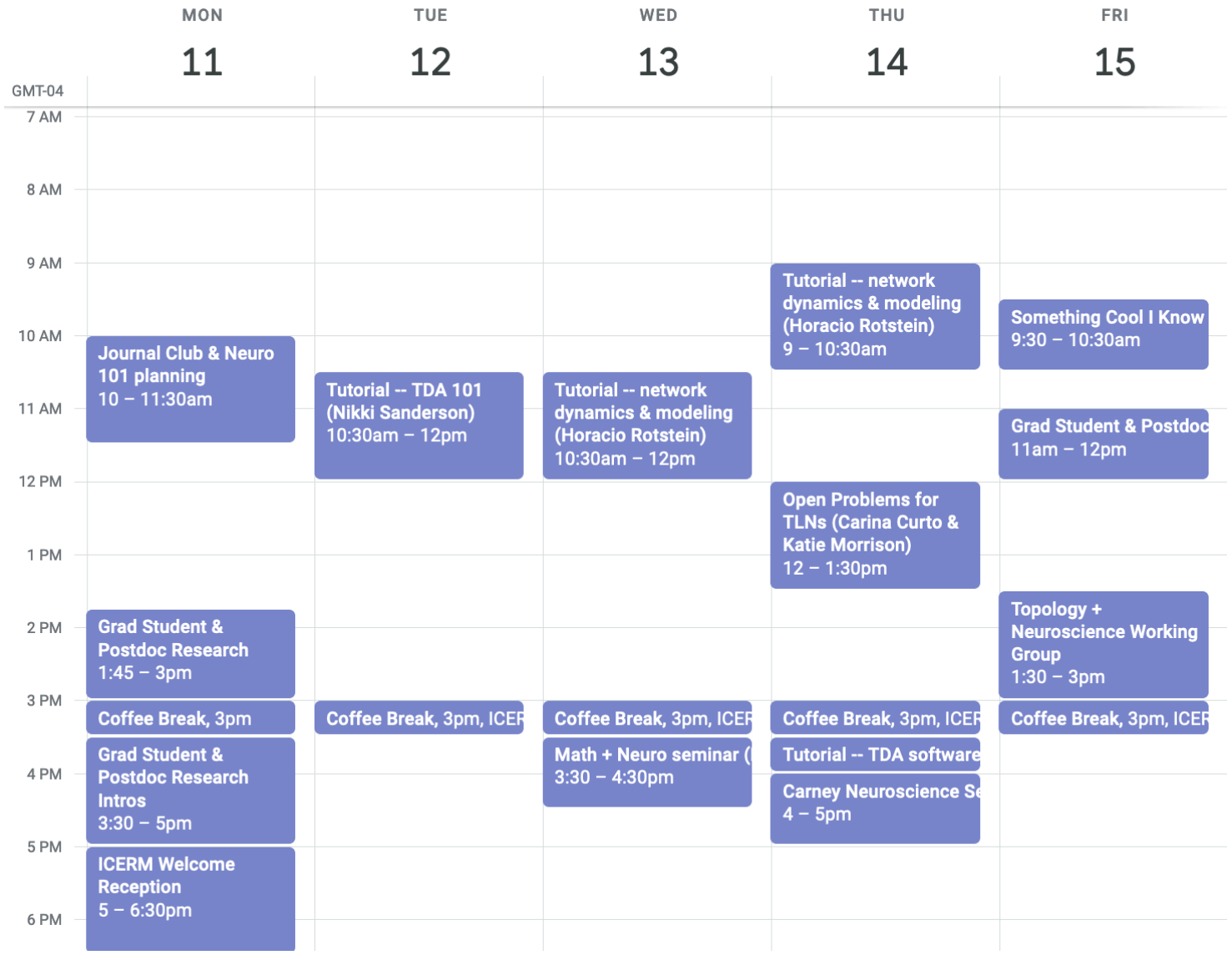
Week 1 (Sept 11–15) Schedule



Organizers

Katie Morrison

- Semester program organizer and organizer of Workshop 1 (Network Dynamics) and Workshop 3 (Neural Coding)
- Professor of mathematics at University of Northern Colorado
- PhD in algebraic coding theory
- Past research in algebraic properties of matrix codes, connections between mathematical coding theory & neural coding, analysis of convex neural codes using applied algebra & combinatorics
- Current research developing the theory of threshold-linear networks (using linear algebra and discrete math techniques) to address neuroscience questions
  - How does neural connectivity shape network dynamics
  - What types of network architectures yield sequences of neural activity

Carina Curto

- Semester program organizer and organizer of Workshop 1 (Network Dynamics) and Workshop 2 (Topology and Geometry)

- Professor of mathematics at Penn State
  – moving to Brown (Applied Math and Carney) in Fall 2024

- A.B. in Physics, PhD in algebraic geometry and string theory

- Past research in mathematical physics (deep past!), neural network theory, algebraic geometry and topology approaches to neural codes

- Current research:
  - threshold-linear networks (TLNs, CTLNs)
  - neuronal assemblies in zebrafish
  - topological approaches to data analysis

Brent Doiron

- Organizer for Workshop 1 (Network Dynamics)
- Professor in the Depts of Neurobiology and Statistics at University of Chicago
- PhD in physics
- Director of Grossman Center for Quantitative Biology and Human Behavior

- Current research applies nonequilibrium statistical mechanics and nonlinear dynamical systems theory to neuroscience questions
  - How do populations of neurons coordinate their activity to perform stimulus representation, decision making, or store memories
  - Understanding the genesis and impact of neuronal "noise" to build better models of brain dynamics and how it supports cognition
- Collaboration with experimental neuroscientists to probe the circuit functioning of diverse sensory and cognitive systems

Robert Ghrist

- Organizer for Workshop 2 (Topology & Geometry)
- Professor in the Depts of Mathematics and Electrical & Systems Engineering at the University of Pennsylvania
- PhD in applied mathematics (motivated by questions from engineering)

- Past research in applications of topology to problems of interest in engineering, e.g. sensor networks, robotics, signal processing, data analysis, optimization, and more
- Current research in applied topology and neuroscience as well as information dynamics over social networks
  - algebraic-topological methods problems of local-to-global integration

Kathryn Hess

- Organizer for Workshop 2 (Topology & Geometry)
- Professor of mathematics at EPFL
- PhD in pure algebraic topology
- Head of Topology & Neuroscience Lab

- Past research in pure homotopy theory, category theory, and algebraic K-theory, and some applications of topology to material science and computer science
- Current research in applied topology and neuroscience
  - topological characterization of structural and functional micro-connectomes
  - topological approaches to classification and synthesis of neuron morphologies

Zack Kilpatrick

- Organizer of Workshop 1 (Network Dynamics) and Workshop 3 (Neural Coding)
- Professor of applied mathematics at University of Colorado
- PhD in mathematical neuroscience

- Research develops methods in statistical mechanics to address neuroscience questions
  - understand impact of complex architecture on solutions of neural field equations (e.g., traveling waves, spiral waves, bumps)
  - impact of stochasticity on spatiotemporal solutions to neural fields
  - asymptotic and weakly nonlinear analysis that can jointly treat network heterogeneities
  - how slow plasticity processes can implement forms of long-term Bayesian inference in bump attractor activity modeling working memory
  - cognitive mechanisms underlying the performance of naturalistic behaviors like foraging

Matilde Marcolli

- Organizer for Workshop 2 (Topology & Geometry)
- Professor of mathematics at Caltech
- PhD in mathematics

- Past research in all kinds of mathematical physics
- Current research in mathematical neuroscience, most interested in applications of mathematics to linguistics

Konstantin Mischaikow

- Organizer for Workshop 1 (Network Dynamics)
- Professor of mathematics at Rutgers University
- PhD in dynamical systems

- Research focus on developing topological methods for understanding nonlinear dynamical systems.
  - How can we use topological invariants to infer statements about the structure of nonlinear dynamics?
  - Can we use topological methods to guarantee the validity of the numerics?
- Current research applying topological methods to multiscale biological systems
  - Develop theoretical and computational tools to derive conclusions from time series data to conclusions about the underlying dynamics that potentially generated the data
  - Use homology to derive accurate mathematical statements even when the models or data lack precision

Tanya Sharpee

- Organizer for Workshop 2 (Topology & Geometry) and Workshop 3 (Neural Coding)
- Professor at the Salk Institute
- PhD in Physics
- Head of Computational Neurobiology Laboratory

Elad Schneidman

- Organizer for Workshop 2 (Topology & Geometry) and Workshop 3 (Neural Coding)
- Professor at the Weizmann Institute
- PhD in Physics
- Head of Learning Networks Lab

Introductions

Tell us about yourself

- Name & current position
- What city/institution are you coming from?
- What field were you trained in?
- Have you done any math+neuro work or other interdisciplinary work before?
- What neuroscience questions are you interested in? (optional)
- What are your mathematical interests or areas of expertise? (optional)
- Hobbies? (sports, music, culinary, …)