Building Networks: Women in Complex & Nonlinear Systems

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Overview

The purpose of this workshop was to bring together researchers with expertise in a wide range of mathematical tools and applications related to complex and nonlinear systems. We had three primary objectives related to building connections and collaborations, helping establish supportive professional communities, and highlighting the work of underrepresented scholars.

Our first goal was to **connect diverse perspectives to initiate new collaborations**. Mathematicians working on different problems in complex systems often use related techniques; nevertheless, because the applications involved are so broad, researchers who would benefit from talking to each other may not have the opportunity to interact. For example, many of the mathematical techniques used to understand intracellular transport, traffic flow, and content spread on social networks are similar, but researchers working on these topics often publish in different journals and attend different conferences. One first goal was, therefore, to connect mathematicians, physicists, and other scientists to build new collaborations between people working across a spectrum of application areas. To achieve this goal, our workshop featured talks from a diverse group of scholars who are representative of the interdisciplinary nature of complex systems. Crucially, the workshop also included structured breakout sessions where groups of attendees (in-person and virtual) discussed open problems and generated numerous research directions as a group. These groups have continued to meet and work on the research projects that started at BIRS.

Our second goal was to **empower early-career researchers and build mentorship networks**. We designed our workshop to increase the visibility, professional connections, and supportive mentorship community of all of our participants. Through breakout sessions, we provided organic opportunities for interaction between experts in the field, early-career faculty, postdocs, and graduate students. We were especially delighted to hear research ideas and projects proposed by early-career participants in our breakout discussions. Throughout the talks and breakout sessions in our workshop, we heard from many young researchers who actively shared their ideas, asked questions, and provided their expertise—it was clear that they felt empowered and valued.

The final goal our of our workshop was to **highlight and support the contributions of underrepresented scholars in complex systems**. Peer networks are both research-productive and critical to the success of underrepresented scholars. In particular, previous Women in Research networks (e.g., AWM research networks) have been very successful, resulting not only in many publications and long-term collaborations, but also in the revitalization of their participants. Alongside our BIRS workshop, we established an AWM Women in Complex and Nonlinear Systems research network. The BIRS workshop was the first time this network met, and the consensus was a clear revitalization of all participants. The time that we had at BIRS was a perfect way to kick off the AWM network, which we expect to continue to grow through future activities (e.g., building on the

success of our kick-off meeting at BIRS, several of us are leading an AWM workshop at the 2024 SIAM Annual Meeting). This network will continue to be open to scientists of all gender identities and strive to support the research of underrepresented groups, increase their visibility, and build lasting communities. We are committed to including a broad group of women (binary, non-binary, and transgender) and their allies, representative of the complex-systems community. We especially strive to support researchers with intersectional experiences, including scholars of color, LGBTQIA scientists, and others who have been historically underserved.

Workshop Structure

We organized a five-day hybrid workshop with 27 participants (13 in-person participants and 14 virtual participants) representing a broad range of research areas from experimental physics, network science, fluid dynamics, collective dynamics, epidemiology and quantum information. Each morning we heard from three of the participants (with equal representation from virtual and in-person participants) and then had structured breakout groups in the afternoon. Below we give more details of our daily workshop activities:

- **Monday:** We kicked off our workshop with a wonderful and inspiring talk given by Karen Daniels. Karen's talk was followed by two excellent talks given by mid-career researchers.

  - Karen Daniels (North Carolina State University): **Building networks (In fact, I'm actually building networks)**
  - Daphne Klotsa (University of North Carolina, Chapel Hill): **A touch of non-linearity: mesoscale swimmers and active matter in fluids**
  - Katie Newhall (University of North Carolina, Chapel Hill): **Effective thermal equilibrium induced by crosslinking proteins in polymer chromosome model**

  We began the afternoon by opening up the floor to the in-person and virtual participants to share any ideas about possible projects. We had one scribe who wrote down all relevant information about the discussion. After a vibrant and lively discussion a total of nine possible research directions where discussed. These were posed by participants from recent graduates to senior researchers. See section page 4 ("Additional Research Ideas Generated") for a full list of these research directions.

- **Tuesday:** Tuesday's three talks—by faculty and postoc fellows—were also extremely stimulating and engaging.

  - Moumita Das (Rochester Institute of Technology): **Soft mechanics and fracture properties of cartilage and cartilage-inspired soft network materials**
  - Tahra Eissa (University of Colorado, Boulder): **Learning efficient representations of environmental priors in neuronal networks**
  - Mari Kawakatsu (University of Pennsylvania): **Diversity and structure in complex social systems: case studies in political polarization & emergent hierarchies**

  In the morning we sent out a poll to participants to rank their top three projects from our discussion on Monday. Poll responses were due by noon. After lunch, we ranked the top three projects and assigned participants to those three. We had about an equal number of participants for each of the three projects. Please see section page 3 ("Collaborative Research

Projects") for a description of these projects. For the last one and a half hours of the day, participants broke our into research groups. Each group had a separate working space and had significant participation from virtual members.

- **Wednesday:** On Wednesday we had three amazing talks and took the afternoon off to hike and enjoy the beauty that Banff has to offer. Our speakers, spanning faculty to postdoctoral-fellow career stages, are listed below:
  - Irina Popovici (US Naval Academy): **A rigorous approach to the dynamics of self-propelled swarms via a novel central manifold approximation technique**
  - Natalia Komarova (University of California, Irvine): **Evolutionary modeling of cancer: Protective effect of aspirin in colorectal carcinogenesis**
  - Alice Schwarze (Dartmouth College): **Connecting dynamics on and of networks to data - motif-based and mean-field approaches**
- **Thursday:** We began our Tuesday morning with two excellent one-hour talks delivered virtually:
  - Laura Miller (University of Arizona): **Using computational fluid dynamics to understand muscle driven movement by soft tissues and bodies: Case studies in tubular hearts and jellyfish**
  - Maria D'Orsogna (California State University, Northridge): **A mathematical model of reward-mediated learning in drug addiction**

  As a result of discussions at Banff, we noticed there was high interest in quantum information shared among the in-person participants. We thus added a talk on this topic to the schedule on Thursday. Our final talk of the workshop was given by Namrata Shukla from Banaras Hindu University, India.
- **Friday:** Most workshops participants were traveling on Friday, so we did not hold talks on this day. Several participants gathered at BIRS and worked on their projects or on organizing future mini-symposiums to continue building on the momentum initiated at BIRS.

Collaborative Research Projects

As a product of the discussions that we held among virtual and in-person participants on Monday, we generated many research ideas and selected three for further collaboration. Here we discuss these three ongoing projects.

- **Library and abortion deserts**: Inspired by food deserts, we want to better understand how access to libraries and books is spatially distributed. Libraries are a resource to which, in theory, everyone in the United States has access. There are records of where U.S. public libraries are located and how they are used (e.g., zip codes, number of annual visits, number of books in circulation, number of events hosted). How has access to library resources changed over the last few decades? How does this relate to changes in population? In an ongoing collaborative project that we initiated at BIRS, we are applying topological data analysis techniques, as well as other approaches, to better how access to libraries has changed. Our project builds on this **data set**.

  As a related project that illustrates how similar mathematical techniques can be applied to a broad range of complex-systems applications, we also want to look at access to abortion

clinics. While it involves very different time scales, this project has some relationship to our above project on library access. It also includes different feedback dynamics that we must consider, and there are many questions that we have: Can we better understand how birthing centers and number of midwives are spatially distributed? How might medical specialties or doctors themselves change as a result of new abortion legislature? We are treating this project carefully, since we acknowledge that this application could attract (potentially critical) attention.

- **What makes a biological system both robust and resilient?** A system is robust if it is not easily damaged, and it is resilient if, when damaged, it can easily 'bounce back'. Robustness and resiliency depend on diversity, heterogeneity, and redundancy. We are interested in better understanding broad features of complex systems that promote robustness and resiliency from a network perspective. For example, there are studies of robustness for power grid networks, and rich work on resiliency across different fields. In neuroscience, how does one build a system that supports complex behaviors, but is flexible? Robustness could also mean that large parameter changes do not lead to qualitative dynamical changes or structural changes. Are there features of network topology that support robustness?

- **Are there interesting trends in networks-based models of influence and social power?** In social psychology, there are conceptual models of how people choose to act: socially derived or internally psychologically derived. There has not been a lot of work that connects models from social psychology with "complex contagion" models of social setting and network structure. It might be of interest to model either a specific system or build more conceptual models to connect these two perspectives. One application that we are interested in is related to work climate and diversity in academic departments. Some reasonable mathematical frameworks that could be used include ordinary differential equations, agent-based models, and game-theoretic perspectives.

Additional Research Ideas Generated

During our time at BIRS, our in-person and virtual participants held lively, stimulating conversations on possible research projects. We had one scribe who documented all of the ideas generated during these conversations. Here we give a brief description of each of the nine potential projects generated. We selected the three collaborative projects that we eventually pursued from this list:

- Library deserts (pitched by Alexandria Volkening): Inspired by food deserts, can we study library access across the United States?

- Abortion clinic access (pitched by Heather Zinn-Brooks): With the recent U.S. supreme court decision to overturn Roe versus Wade, access to abortion clinics will be made difficult in some states. Can we better understand abortion access across the United States?

- Robustness and resilience (pitched by Moumita Das): Can we study robustness and resilience in general biological networks?

- Fitting data to co-evolving dynamics (pitched by Alice Schwarze): Can we study the interplay between co-evolving models of opinion dynamics and game-theoretic models?

- Network-based models of influence and social power (pitched by Nina Fefferman): Can we develop network models to study influence and social power?

- Departmental service in universities (pitched by Nancy Rodriguez): Can we do a massive data-collection effort to obtain information on equity of service across academic departments in the United States?
- Nested hierarchical networks (pitched by Namrata Shukla): Can we study the flow of information from larger graphs to subgraphs and vice versa?
- Approaching failure transition by becoming more or less consistent (pitched by Karen Daniels): Can we develop toy models that lead to failure in these two (seemingly contradictory ways) of becoming more or less consistent, by changing parameters?
- Network dynamics under constraints (pitched by Mari Kawakatsu): Can we study dynamics on networks, but with constraints?

WICANS Norms

It is important for our research and mentorship network to enable healthy and fruitful collaboration. To ensure this, we had a discussion at BIRS about some important norms that we aim to follow. With regards to any publications that come out of this work, it has been established that everyone in the research group will be an author of the paper. Moreover, we discussed the problem that women's papers are cited less frequently, and we pledged to cite each others work when it is relevant. Furthermore, we are ambassadors of each others' work and will share any new papers and results from members of our network to other colleagues and networks.

Statistics

Our workshop included active participation virtually and in person, with an emphasis on providing unstructured time for collaboration building. Five speakers presented their research virtually, and six speakers shared their work in person. The workshop participants spanned career stages, with seven full professors, six associate professors, seven tenure-track assistant professors, six postdoctoral researchers (including several in the first months of their positions), and one professional outside academia. Our workshop drew participants from four countries, and included five researchers from primarily undergraduate institutions. Based on our identifications, there were 27 women participants and five of these participants also belonged to underrepresented minority communities.

Conclusion

Our workshop accomplished the three goals that we set out to achieve. We connected women from various disciplines though our research project groups. We also empowered early-career researchers by giving them a forum to share their work and share their research ideas, in an environment that valued their expertise and served as a supportive community. A forum was also provided to underrepresented scholars. Most importantly we enjoyed a wonderful and inspiring week at BIRS, with great science, great conversations, and wonderful hikes. Our participants reported leaving their time at BIRS feeling re-energized. We are so grateful to have had the opportunity to spend a week at BIRS and are indebted to all of the BIRS staff who made the week a success.