PHYS 5126 Contagion on Networks

Spring 2020 – PHYS 5126 (38742) – Northeastern University

Instructor:	Samuel V. Scarpino	**Time:**	MR 1145-1325
Email:	s.scarpino@northeastern.edu	**Location:**	Ryder 431
Office Hours:	R 1330-1530 (or by appt.)	**Office:**	177 Huntington 2nd Floor

NU PATH Categories: Engaging with the Natural and Designed World & Analyzing and Using Data.

Course Pages: Northeastern Blackboard.

Main References:

- *Networks 2nd Edition* by Newman, M. (2018) Oxford University Press.
- *Mathematics of Epidemics on Networks: From Exact to Approximate Models* by Kiss, Miller, and Simon (2017) Springer.

Course Description: From biological pathogens, e.g., Ebola, SARS, and influenza, to social contagions, such as fake news, methods from network science provide powerful tools for understanding and investigating contagious processes in the natural and modern world. This course covers the properties of diverse networks and explores foundational methods for studying contagions on networks. Moving beyond description, a key objective of the course is to synthesize the diversity of mathematical/computational approaches and model frameworks in order to investigate how scientists study contagion using methods from physics and network science.

Course Objectives:

1. Develop a foundational understanding of contagion on networks and how they can be used to understand diverse natural systems.
2. Understand how approaches from physics allow us to uncover remarkable regularities in networked systems.
3. Construct a computational toolkit for analyzing and visualizing contagions on networks.
4. Enhance critical and analytical thinking skills needed to interpret primary scientific literature.
5. Learn to evaluate popular writing on scientific issues.
6. Improve written and verbal communication skills.

Learning outcomes: Successful completion of this class will result in the following learning outcomes:

1. Apply the scientific method to study networks and contagion.
2. Communicate statistical and computational results to both scientific and non-scientific audiences.
3. Critically read, interpret, and explain concepts from the primary, scientific literature.
4. Explain why network science is a powerful tool for studying natural systems.
5. Identify various models of contagion on networks and computationally determine key aspects of their structure and function.

Assignments & Grading Breakdown:

Proposal - Research Project (10%) – The main assignment for this course is a research project. Ideally, this project will be tailored to your individual areas of interest and career goals. For example, you might consider writing an "NSF-style" graduate research fellowship or postdoctoral fellowship application. Student can decide whether to focus these two pages on network science training or network science research. Formatting requirements will follow NSF guidelines for the biology postdoctoral competition, see https://www.nsf.gov/pubs/2015/nsf15501/nsf15501.htm, or for the GRFP, see https://www.nsfgrfp.org/applicants/application_components/statements. For the GRFP, and perhaps for postdoctoral fellowships, there are examples of successful and unsuccessful applications here https://www.ogrants.org/programs#nsf-graduate-research-fellowship The first aspect of this assignments will be a short paragraph describing the research area and the format, e.g., paper, application, etc., you plan to follow.

Pedagogical presentation on contagion and networks (10%) – Each student (or team depending on the number enrolled in the course), will give a 30 minute tutorial on one aspect of networks and/or contagion to the class. I will work with each individual/team to identify an appropriate topic.

Outline - Research Project (20%) – Part two of your research project assignment consists of an outline and annotated bibliography. I will provide examples and a rubric.

First draft - Research Project (15%) – Papers should be formatted for a field-appropriate journal or fellowship application. Specific parameters for each student's paper will be determined based on the outline and annotated bibliography. You will also be asked to give a brief, i.e. 12 minute, presentation on your work to the class.

Peer review - Research Project (15%) – Each student will provide a peer review of another student's first draft. Grades will be based on the quality of your evaluation and on how effectively you communicate your suggestions. Again, I will provide examples and a rubric.

Final draft - Research Project (20%) – The majority of your grade on the final draft will be based on how well you respond to peer review comments, which will also include specific comments from me. I will provide examples and a rubric.

Participation (10%) – Your participation grade is based on your in-class work, attendance, and respect for the technology policy. More than three unexcused absences will result in a failing grade for the course.

Important Dates:

MLK Holiday (No Monday Class)	Jan. 20th
Research Project Proposal	Jan. 23rd
Add/Drop Deadline	Jan. 27th
Research Project Outline	Feb. 13th
Presidents Day (No Monday Class)	Feb. 17th
Spring Break (No Class M/R)	Mar 2nd - 6th
Research Project First Draft	Mar. 19th
Research Project Peer Review	Apr. 2nd
Research Project Final Draft	Apr. 16th
Patriots Day (No Monday Class)	Apr. 20th

Course Schedule:

Date(s)	Material	To Do
Week 1	Intro to contagion	*Reading 1*
Week 2	Network Science overview	*Reading 2*
Week 3	Modeling contagion on networks I	*Reading 3* & Proposal Due
Week 4	Modeling contagion on networks II	*Reading 4*
Week 5	Exact propagation models	*Reading 5*
Week 6	Mean-field approximations	*Reading 6* & Outline Due
Week 7	Vaccination and other interventions	*Reading 7*
Week 8	Dynamic and adaptive networks	*Reading 8*
Week 9	Message passing and contagion on networks	*Reading 9*
Week 10	Interacting contagions	*Reading 10* & First Draft Due
Week 11	Contagions in meta-population, multiplex and multi-layer networks	*Reading 11*
Week 12	Memory and Non-Markovian dynamics	*Reading 12* & Peer Review Due
Week 13	Social media & fake news	*Reading 13*
Week 14	Research presentations	Final Papers Due

Readings:

1. Goffman & Newill 1964.
2. Chapters 1, 3 and 5 - Networks: An Introduction.
3. Chapter 17 - Networks: An Introduction AND Chapter 1 - Mathematics of Epidemics on Networks.
4. Meyers et al. 2005, Pastor-Satorras et al. 2015, and Pastor-Satorras & Vespignani 2001.
5. Chapters 2 & 3 - Mathematics of Epidemics on Networks.
6. Chapters 4 & 5 - Mathematics of Epidemics on Networks.
7. Holme 2005, Pourbohloul et al. 2005, and Tong et al. 2010.
8. Chapter 8 - Mathematics of Epidemics on Networks & Scarpino et al. 2016, Gross et al. 2006, & Petri, G., & Barrat.

9. Shrestha et al. 2015, Castellano & Pastor-Satorras 2018, & Cantwell & Newman 2019.
10. Hebert-Dufresne & Althouse 2015 & Hebert-Dufresne et al. 2019.
11. Colizza et al. 2007, Gomez et al. 2013, De Domenico et al. 2016, & de Arruda et al. 2017.
12. Dodds & Watts 2004 and Chapter 10 - Mathematics of Epidemics on Networks.
13. Papadopoulos et al. 2012, Foucault Welles et al. 2014, Lazer et al. 2018, and Tornberg 2018.

Primary Literature:

- Castellano, C., & Pastor-Satorras, R. (2018). Relevance of backtracking paths in recurrent-state epidemic spreading on networks. Physical Review E, 98(5), 052313.
- Cantwell, G. T., & Newman, M. E. J. (2019). Message passing on networks with loops. arXiv preprint arXiv:1907.08252.
- Colizza, Vittoria, Romualdo Pastor-Satorras, & Alessandro Vespignani. "Reaction–diffusion processes and metapopulation models in heterogeneous networks." Nature Physics 3.4 (2007): 276.
- de Arruda, G. F., Cozzo, E., Peixoto, T. P., Rodrigues, F. A., & Moreno, Y. (2017). Disease localization in multilayer networks. Physical Review X, 7(1), 011014.
- De Domenico, M., Granell, C., Porter, M. A., & Arenas, A. (2016). The physics of spreading processes in multilayer networks. Nature Physics, 12(10), 901-906.
- Dodds, P. S., & Watts, D. J. (2004). Universal behavior in a generalized model of contagion. Physical review letters, 92(21), 218701.
- Foucault Welles, B., Vashevko, A., Bennett, N., & Contractor, N. (2014). Dynamic models of communication in an online friendship network. Communication Methods and Measures, 8(4), 223-243.
- Goffman, W., & Newill, V. A. (1964). Generalization of epidemic theory: An application to the transmission of ideas. Nature, 204(4955), 225-228.
- Gomez, S., Diaz-Guilera, A., Gomez-Gardenes, J., Perez-Vicente, C. J., Moreno, Y., & Arenas, A. (2013). Diffusion dynamics on multiplex networks. Physical review letters, 110(2), 028701.
- Gross, T., D'Lima, C. J. D., & Blasius, B. (2006). Epidemic dynamics on an adaptive network. Physical review letters, 96(20), 208701.
- Hebert-Dufresne, L., & Althouse, B. M. (2015). Complex dynamics of synergistic coinfections on realistically clustered networks. Proceedings of the National Academy of Sciences, 112(33), 10551-10556.
- Hebert-Dufresne, L., Scarpino, S. V., & Young, J. G. (2019). Interacting contagions are indistinguishable from social reinforcement. arXiv preprint arXiv:1906.01147.
- Holme, P. (2004). Efficient local strategies for vaccination and network attack. EPL (Europhysics Letters), 68(6), 908.
- Lazer, D. M., Baum, M. A., Benkler, Y., Berinsky, A. J., Greenhill, K. M., Menczer, F., ... & Schudson, M. (2018). The science of fake news. Science, 359(6380), 1094-1096.

- Meyers, L. A., Pourbohloul, B., Newman, M. E., Skowronski, D. M., & Brunham, R. C. (2005). Network theory and SARS: predicting outbreak diversity. Journal of theoretical biology, 232(1), 71-81.
- Pastor-Satorras, R., & Vespignani, A. (2001). Epidemic spreading in scale-free networks. Physical review letters, 86(14), 3200.
- Pastor-Satorras, R., Castellano, C., Van Mieghem, P., & Vespignani, A. (2015). Epidemic processes in complex networks. Reviews of modern physics, 87(3), 925.
- Petri, G., & Barrat, A. (2018). Simplicial activity driven model. Physical review letters, 121(22), 228301.
- Papadopoulos, F., Kitsak, M., Serrano, M. Á., Boguná, M., & Krioukov, D. (2012). Popularity versus similarity in growing networks. Nature, 489(7417), 537.
- Pourbohloul, B., Meyers, L. A., Skowronski, D. M., Krajden, M., Patrick, D. M., & Brunham, R. C. (2005). Modeling control strategies of respiratory pathogens. Emerging infectious diseases, 11(8), 1249.
- Scarpino, S. V., Allard, A., & Hebert-Dufresne, L. (2016). The effect of a prudent adaptive behaviour on disease transmission. Nature Physics, 12(11), 1042.
- Shrestha, M., Scarpino, S. V., & Moore, C. (2015). Message-passing approach for recurrent-state epidemic models on networks. Physical Review E, 92(2), 022821.
- Tong, H., Prakash, B. A., Tsourakakis, C., Eliassi-Rad, T., Faloutsos, C., & Chau, D. H. (2010). On the vulnerability of large graphs. In 2010 IEEE International Conference on Data Mining (pp. 1091-1096). IEEE.
- Tornberg, P. (2018). Echo chambers and viral misinformation: Modeling fake news as complex contagion. PloS one, 13(9), e0203958.

Course policies:
I. Grades – 100–93% (A), 92–90% (A-), 89–87% (B+), 86–83% (B), 82–80% (B-), 79–77% (C+), 76–73% (C), 72–70% (C-), 69–60% (D), <60% (F).

II. Technology – Please silence and put away all electronics before coming to class–there should be zero texting in class. Computers should be used only for course-related work and only when someone isn't addressing the class. Violation of these policies will negatively affect your participation grade (and your understanding of course material).

III. Turning in assignments – All assignments must be turned in on Blackboard.

IV. Late assignments – Late or missed assignments will be given a score of 0%. Please contact me if you have a documented emergency.

V. Email – I am happy to answer questions via email, but cannot promise to respond same-day. Please remember that email is a professional, mostly-permanent record, so please communicate in a respectful manner.

VI. Academic honesty – As in all Northeastern classes, academic honesty will be expected and departures will be dealt with appropriately. Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation, see http://www.northeastern.edu/osccr/academic-integrity-policy/ for guidelines.

University policies & information:
Absences: Because the Northeastern University Health and Counseling Services Center does not provide documentation for excused absences, you are on the honor system for attendance. However, you should remember that being dishonest about why you missed a class and/or assignment can be considered a violation of the University's academic honesty policy. I do not plan on taking daily attendance, but will instead assign non-graded in-class quizzes. If you miss more than four in-class quizzes due to unexcused absences, you will be given a failing grade for the course. If you miss more than five lectures for any reason, you may be given a failing grade for the course and must contact me ASAP.

Academic assistance: Anyone needing accommodation please contact me as soon as possible. Students who have disabilities may wish to consult the Disability Resource Center http://www.northeastern.edu/drc/getting-started-with-the-drc for aid with resources and accommodation. Those who wish to receive academic services and accommodations must present their accommodation letters from the DRC at the beginning of the semester so that accommodations can be arranged in a timely manner.

Religious holidays: You have the right to practice the religion of your choice and can make-up missed work due to your religious holidays. For those requesting an accommodation due to a religious holiday, please submit a schedule of your holidays to me by the end of the second full week of classes.

Title IX: The University strictly prohibits sex or gender discrimination in all university programs and activities. Information on how to report an incident of such discrimination (which includes sexual harassment and sexual assault) is located at http://www.northeastern.edu/titleix

Tutoring and other resources: The University and the College operate many centers in support of student learning. Many of these centers do no require additional fees beyond tuition and fees associated with standard registration. The University operates a College Reading and Learning Association certified peer-tutoring center (see http://www.northeastern.edu/csastutoring/ for more information).