

# Emerging Models and Paradigms in Network Science

## Part #0: Introduction

*Ph.D. Course at University of Calabria*

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# Course schedule

- Monday 27/05, 14:30 – 17:30: [Introduction + Temporal Networks](#)
- Tuesday 28/05, 14:30 – 17:30: [Multilayer Networks](#)
- Wednesday 29/05, 14:30 – 17:30: [Stream Graphs + Higher-Order Interactions](#)
- Thursday 30/05, 14:30 – 17:30: [Higher-Order Interactions + Network Science project](#)

# Who am I?

**Francesco Cauteruccio** (he/him) received the **Ph.D. in Mathematics and Computer Science** from the **University of Calabria** in January 2018. Currently, he is a **Tenure-Track Assistant Professor** at the Department of Information Engineering, Electrical Engineering and Applied Mathematics (DIEM) at the **University of Salerno** (Italy). He has been a visiting researcher at the Department of Artificial Intelligence and Cybersecurity, **Alpen-Adria-Universität** (Austria) and a visiting Ph.D. student at CREATIS, **Université Claude Bernard Lyon 1** (France).

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# What do I do?

- **Social and Complex Network Analysis**
  - *Phenomena in Computational Social Science*
  - *Network-based modeling of complex systems*
  - *Network and Hypernetwork Science*
- Data Science
- Logic Programming and methods for coupling inductive and deductive reasoning
- Internet of Things
- Advanced Algorithms for Sequences Comparison



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# Motivation I

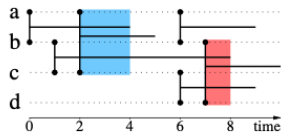
- Network Science
  - Network science is an interdisciplinary field that studies the structure and behavior of complex networks, including social networks, biological networks, and technological networks.
  - It involves the use of mathematical models and computational tools to analyze how network structures influence the dynamics and functionalities of the systems they represent.
- Why Network Science is useful
  - **Understanding complex systems**
    - **Interconnectedness** – Network science helps reveal how components in a system are interconnected.
    - **Patterns and Relationships** – Identifies patterns and relationships that are not apparent when studying individual components in isolation.
  - **Modeling real complex systems.**
  - **Enhancing data analysis.**

# Motivation II

- Real complex systems are multi-dimensional and exhibit timevarying relationships.
  - Therefore, **network science needs to adapt and provide suitable models and computational tools to deal with these aspects.**
- Old-but-gold and novel models in Network Science
  - *Temporal Networks* – how to deal with time [3],
  - *Multilayer Networks* – how to deal with multiple types of interactions [2],
  - *Stream Graphs* – how to deal with interactions in time [4],
  - *Hypernetworks* – how to deal with non-dyadic relationships [1].
- ... but why?
  - They reflect reality and enhance predictive power.
  - Better solution to complex problems.

# Overview of the course

- We start by discussing old-but-gold models
  - *Temporal Networks*,
  - *Multilayer Networks*.
- Then, we discuss novel ones
  - *Stream Graphs*,
  - *Hypernetworks*
- For each topic, we make some coding exercises
  - Python programming language is suggested.
- The course involves a final project:
  - *An empirical study of a certain phenomenon on a network dataset*,  
or
  - *Definition of a (possibly novel) problem on the discussed models*.



**Figure:** Viz of a stream graph with maximal compact cliques highlighted. Source: [4]





# Repository

- We have a GitHub repository
  - <https://github.com/finalfire/networkscience-phdcourse-2024>
- Some slides will report a partial link to it
  - e.g., `examples/temporal-network-0.md` indicates the file `temporal-network-o.md` within the directory `examples` at the root of the repository.





# References I

-  [Federico Battiston, Giulia Cencetti, Iacopo Iacopini, Vito Latora, Maxime Lucas, Alice Patania, Jean-Gabriel Young, and Giovanni Petri.](#)  
Networks beyond pairwise interactions: Structure and dynamics.  
*Physics Reports*, 874:1–92, 2020.
-  [Stefano Boccaletti, Ginestra Bianconi, Regino Criado, Charo I Del Genio, Jesús Gómez-Gardenes, Miguel Romance, Irene Sendina-Nadal, Zhen Wang, and Massimiliano Zanin.](#)  
The structure and dynamics of multilayer networks.  
*Physics reports*, 544(1):1–122, 2014.
-  [Petter Holme and Jari Saramäki.](#)  
Temporal networks.  
*Physics reports*, 519(3):97–125, 2012.
-  [Matthieu Latapy, Tiphaine Viard, and Clémence Magnien.](#)  
Stream graphs and link streams for the modeling of interactions over time.  
*Social Network Analysis and Mining*, 8:1–29, 2018.