**Titolo**: Extracting essential information and dynamics from complex networks

**Codice Progetto:** 2022MBC2EZ

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**Partner-Unità di ricerca**: Politecnico di Torino

**CUP**: C53C24000810006

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**Durata**: 05/02/2025 – 04/02/2027 (24 mesi)

**Budget totale progetto:** 272.859,00 €

**Budget UNIPD:** 205.340,00 €

**Abstract del Progetto:** Dynamic network models are an essential tool for the analysis and control of biological, physical and social phenomena. As the number of nodes and edges grows their analysis and simulation becomes prohibitive. Yet, in most applications the aim is to answer structural or high-level questions whose answers exhibit little or no dependence on the "microscopic" description of the network, making its complexity largely irrelevant. This is true for continuous-state network models as well as finite state models, including those used for epidemic systems, gossip interactions in opinion dynamics, learning and evolutionary games.

Most applications share common features:

1. Even for medium size networks and low dimensional state spaces of the nodes, both simulation and inference become intractable.

2. Neither the network nor the state are known exactly and there may be restrictions on the admissible configurations.

3. The interest is often on the structural organization of the network (e.g., the presence of hierarchical structures, the degree of controllability of the network, and/or the "small world" property) or on the behavior of certain macro-observables (e.g., the number of infected individuals and the extent of the contact between infected or not infected in an epidemic model, the polarization of opinions in a social network model, or rather the spread of a mutant species in a biological system).

4. Interventions and control actions can only be done at a macro level prescribing laws for all nodes in a region (e.g., when performing neurostimulation only a whole region of the brain can be targeted), or for all nodes with certain characteristics (e.g., rules in epidemiological emergencies, taxes in economic systems).

Items 1. and 2. indicate that microscopic models are way too large to be profitably analyzed in detail and/or inferred from data, but 3. and 4. also suggest that typically not all that complexity is really needed and only a macroscopic description may be sufficient.

The main goal of the project is to develop methods to construct reduced aggregated models that can be used for decision and control purposes, exploiting symmetries while capturing relevant structural information. Understanding how this aggregation can be performed for network systems and which is the optimal grain for the

given high-level task is a formidable problem that calls for novel tools, especially if a fully automated algorithm is sought that is also robust to noise and limited information.

Our approach relies on the definition of a new continuous (and hence tractable) measure balancing the complexity of the network with the prior information about structural organization of the network and/or with the macro-observable under scrutiny.

The potentially groundbreaking research goals of this proposal are mainly motivated by two formidable applications that will also represent a testbed for our project, namely network models for the brain dynamics and epidemic spread.

Ministero dell'Università e della Ricerca

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