UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Fisica e Chimica - Emilio Segrè
ACADEMIC YEAR	2020/2021
MASTER'S DEGREE (MSC)	PHYSICS
INTEGRATED COURSE	COMPLEX NETWORKS
CODE	19764
MODULES	Yes
NUMBER OF MODULES	2
SCIENTIFIC SECTOR(S)	FIS/07
HEAD PROFESSOR(S)	MICCICHE' SALVATORE Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	MICCICHE' SALVATORE Professore Ordinario Univ. di PALERMO
CREDITS	6
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	2
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**MICCICHE' SALVATORE** Tuesday 15:00 17:00 Dipartimento di Fisica e Chimica, Viale delle Scienze, Ed. 18, Studio del docente. Gli studenti sono pregati di iscriversi tramite portale UNIPA. \\ Department of Physics and Chemistry, Viale delle Scienze, Ed. 18, Lecturer's office. Students are requested to register through the UNIPA portal.

DOCENTE: Prof. SALVATORE MICCICHE'

PREREQUISITES	Knowledge of a programming language.
LEARNING OUTCOMES	Knowledge and ability to understand - Acquisition of the basic concepts of complex networks Ability to apply knowledge and understanding - Ability to apply the fundamental concepts to the study of stylized complex systems. Autonomy of judgment - The course stimulates a critical approach to the learning of concepts and in the solution of complex networks problems, also taking into account computational issues. Communicative skills - Students are invited to interact during the lesson, exposing their evaluation and their opinion about the considered topic, also taking into account computational issues. Learning skills - The autonomous approach of the student is stimulated in the search for theoretical and computational solutions best suited for the representation and study of model and real complex networks. All student's skills are carefully evaluated during the exam.
ASSESSMENT METHODS	The exam consists of a few phases. The first phase concerns the resolution of problems and / or to answer questions concerning the main concepts of Complex Networks. The second phase consists of a computational test, which involves writing a short code for the quantitative description of a complex network. The test will allow to verify the degree of knowledge of the concepts of complex networks tought at the course. In particular, the ability to analyze as well as the ability to obtain quantitative results will be highlighted. The test will also discuss the topics developed during the course and the resolution of problems proposed to the candidate. In addition to the knowledge of the candidate and his ability to apply them, this test also allows to evaluate the possession of scientific language properties and clear and direct exposure skills. The final graded evaluation will be formulated on the basis of the following conditions: a) Basic knowledge of the models and applications of complex networks studied and limited capacity to apply them autonomously, sufficient capacity for analysis of the presented phenomena and of the exposure of the procedures followed (vote 18-21); b) Good knowledge of the models and applications of studied complex networks and ability to apply them autonomously to situations similar to those studied, discrete capacity for analysis of the phenomena presented and for the exposure of the procedures followed (grade interval 22-25); c) In-depth knowledge of the models and applications of studied complex networks and the ability to apply them to unknown conditions, even with some hesitation, good ability to analyze the presented phenomena and to show the procedures followed (grade interval 26-28); d) In-depth and widespread knowledge of the models and applications of studied complex networks and ability to apply them promptly and correctly to unknown complex networks, excellent ability to analyze the phenomena presented and excellent communication skills (grade interval 29-30L).
TEACHING METHODS	The course is given during one term and includes both classroom lectures and lectures in the Computer Classroom. The teaching activity is developed through lessons and numerical/practical exercises in which problems are solved, which aim to test student's skills to apply the acquired knowledge.

MODULE COMPLEX NETWORKS APPLICATIONS *Prof. SALVATORE MICCICHE'*	
SUGGESTED BIBLIOGRAPHY	
Materiale fornito dal docente./Material provided by the lecturer. Testi di Consultazione/Reference books: - Newman, M., 2010. Networks: an introduction. Oxford University Press. ISBN: 9780198805090. - Barabasi, A.L. and Posfai, M., 2016. Network science. Cambridge University Press. ISBN: 978-0199206650. - Latora, V., Nicosia, V. and Russo, G., 2017. Complex networks: principles, methods and applications. Cambridge University Press. ISBN: 978-1107103184	
AMBIT	20901-Attività formative affini o integrative
INDIVIDUAL STUDY (Hrs)	51
COURSE ACTIVITY (Hrs)	24
EDUCATIONAL OBJECTIVES OF THE MODULE	
The aim of the course is to provide the basic knowledge for the generation and analysis of complex networks and their partitioning into communities.	

SYLLABUS

Hrs	Frontal teaching
2	Introduction to the course. Adjacency lists and calculation of network metrics.
1	Networks visualisation: Pajek, Cytoscape, gephi.
3	Calculation of network metrics: connected components and betweenness. Dijkstra algorithm for the determination of the shortest distance paths.
2	Generation according to Erdős-Rényi and small-world models and analysis of networks with fixed-scale degree distribution.
2	Generation according to the core-periphery models and preferential attachment and analysis of networks with scale-free degree distribution.
2	Implementation of the networked SIR model.
2	Introduction to Community Detection algorithms: general concepts. Classic algorithms: single linkage and Girvan-Newman algorithm. Definition of modularity. Girvan-Newman null model.
2	Community detection algorithms based on the maximization of modularity: Newman's algorithm, Blondel et al. algorithm, Dutch-Arenas (Radatool) algorithm.
2	Community detection algorithms based on Random Walk: Rosvall et al (Infomap) algorithm. Application to the real networks.
2	The configuration model and rewiring techniques. Search for communities in rewired networks.
2	Statistically validated networks. Community characterization. Tests on networks and reqwired networks. Measures of similarity amongst partitions. Correlation-based Networks.
2	Motifs

MODULE **COMPLEX NETWORKS MODELS** *Prof. SALVATORE MICCICHE'*	
SUGGESTED BIBLIOGRAPHY	
Testo di riferimento: - Newman, M., 2010. Networks: an introduction. Oxford university press. Testi consigliati per approfondimenti: - Barabasi, A.L. and Posfai, M., 2016. Network science. Cambridge university press. - Latora, V., Nicosia, V. and Russo, G., 2017. Complex networks: principles, methods and applications. Cambridge University Press.	
AMBIT	20901-Attività formative affini o integrative
INDIVIDUAL STUDY (Hrs)	51
COURSE ACTIVITY (Hrs)	24
EDUCATIONAL OBJECTIVES OF THE MODULE	
The teaching unit aims to introduce students to the main models of complex networks. In particular we will discuss: The Erdos-Renyi model, the small world model, the core periphery model, the scale free network model and the group of models called exponential random graphs. We will briefly discuss the concept (i) of "configuration model", (ii) of resilience of a network to attacks or malfunctions, and (ii) of diffusion on a network. The objective is to familiarize students with models of complex networks and to realize under what conditions the cited models approximate real networks.	

SYLLABUS

Hrs	Frontal teaching
2	Introduction: Examples of complex networks. Internet and the World Wide Web. Network science as a multidisciplinary approach. The concepts of feedback, hierarchical organization, and emergence.
2	Percolation on lattices. Disordered systems. Phase transition in percolation. The Cayley tree.
2	Complex networks. Basic indicators of a network. Degree, betweenness, clustering coefficient, diameter.
2	Visualization and measuring of network indicators. Introduction to some computer tools to visualize and to measure network metrics.
2	The first example of a complex network. The Erdős-Rényi (ER) graph and its properties. Percolation transition in the ER model.
2	Small world model. The Milgram experiment and its contemporary version. “Six degrees of separation”. Distance and clustering coefficient in a small world network.
2	Scale free network. Network growth in the presence of preferential attachment. Mean field solution of a scale free network. Some variants of the basic model.
2	Core-periphery structure. Maximum entropy for network construction. The approach of minimum density. A real example: The interbank market
2	The class of models "exponential random graphs". The two-star model. Stauss’s model. A time dependent model of network formation. Hysteresis in network dynamics.
2	Structural balance. Positive and negative relationships in networks. The concept of structural balance. Structures of balanced networks. Strong form, weak form and generalization of structural balance.
2	Motifs concept in complex networks. Motifs in social networks. Motifs detection and comparison with a null hypothesis. Motifs in a directed graph. Basic motifs. Algorithms to find motifs. Shuffling ,methods in directed networks.
2	Diffusion on networks. The SI (susceptible infected) and SIR (susceptible infected recovered) models in epidemiology. Models of epidemics on networks. The problem of the diffusion of innovation.