UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Fisica e Chimica - Emilio Segrè
ACADEMIC YEAR	2022/2023
MASTER'S DEGREE (MSC)	PHYSICS
SUBJECT	COMPLEX NETWORKS
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20901-Attività formative affini o integrative
CODE	21958
SCIENTIFIC SECTOR(S)	FIS/07
HEAD PROFESSOR(S)	MICCICHE' SALVATORE Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	102
COURSE ACTIVITY (Hrs)	48
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	COMPLEX NETWORKS - Corso: DATA, ALGORITHMS, AND MACHINE INTELLIGENCE COMPLEX NETWORKS - Corso: DATA, ALGORITHMS AND MACHINE INTELLIGENCE
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 understanding - Acquisition of the basic concepts of complex networks Applying knowledge and understanding - Ability to apply the fundamental concepts to the study of stylized complex systems. Making judgements - 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).
EDUCATIONAL OBJECTIVES	The course 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 class of models called "exponential random graphs". We will briefly discuss the concepts of "configuration model", resilience of a network to attacks or malfunctions, and network diffusion. Finally, the main methods of partitioning community networks will be discussed. A first educational objective is to familiarize students with models of complex networks and to realize under which conditions the aforementioned models approximate real networks. A further objective of the course is to provide the basic knowledge for the generation and analysis of complex networks and their partitioning in communities.
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.
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

SYLLABUS

Hrs	Frontal teaching
2	LT01 - Introduction: examples of complex networks. Internet and the World Wide Web. The science of complex networks as a multidisciplinary approach. The concepts of feedback, hierarchical organization and emergence.
2	LT02 - Complex networks. Basic network metrics. Degree, "betweenness", clustering coefficient, diameter of a network.
2	LA01 - Adjacency lists and Adjacency matrices. Calculation of network metrics I: degree and strenght.
2	LA02 - Calculation of network metrics II: connected components and betweenness. Dijkstra's algorithm for the determination of minimum distance paths.
2	LA03 - Visualization and measurement of network indicators. introduction to some IT tools to visualize networks and measure different metrics characterizing complex networks.
2	LT03 - The Erdos-Renyi (ER) network and its properties
2	LT04 - "Scale free" networks. Growth of the network in the presence of "preferential attachment".
2	LT05 - The "Core-periphery" model. The method of maximum entropy in the construction of networks. The minimum density approach.
2	LT06 - The "small world" model. The Milgram experiment and its contemporary version. "Six degrees of separation". Distance on the network and clustering coefficient in a "small world" network.
2	LA04 - Generation according to Erdos-Renyi and small-world models and analysis of networks with fixed-scale degree distribution.
2	LA05 - Generation according to core-periphery and preferential attachment models and analysis of networks with scale-free degree distribution.
2	LT07 - The class of models named "Exponential Random Graphs". The "two-star" model. The Stauss model. A time-dependent model of network formation. Hysteresis in network dynamics.
2	LT08 - Percolation on lattices, disordered systems. Phase transition in percolation. The Cayley Tree.
2	LT09 - Percolation on network. Percolation transition in the ER model.
2	LT10 - Redundancy and Resilience in Complex Networks
2	LT11 - "Structural balance". Relations between positive and negative nodes in networks. The concept of "structural balance". Structure of balanced networks. Strong form and weak form of the "structural balance".
2	LT12 - Spread of epidemics models. The fully mixed susceptible infected recovered (SI) and susceptible infected recovered (SIR) models.
2	LT13 - Spread of epidemics models on networks.
2	LT14 - Introduction to Community Detection algorithms: general concepts. Classical algorithms: single linkage and Girvan-Newman algorithm. Definition of modularity. Girvan-Newman null model.
2	LT15 - Community detection algorithms based on the maximization of modularity: hints on the algorithm of Newman, of Blondel et al., of Dutch-Arenas (Radatool).
2	LT16 - Community detection algorithms based on Random Walk: hints on the algorithm Rosvall et al (Infomap). Real network applications.
2	LT17 - The Configuration model and rewiring techniques. Research of communities in rewired networks.
2	LT18a - Characterization of communities. LT18b - Statistically validated networks.
2	LT19 - The concept of "Motifs" in complex networks. The motifs in the social networks. Detection of motifs comparing the results with a null hypothesis. Motifs in a direct graph. Basic examples of motifs. Algorithms to find motifs.