# UNIVERSITÀ DEGLI STUDI DI PALERMO

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| **DEPARTMENT** | Fisica e Chimica - Emilio Segrè |
| **ACADEMIC YEAR** | 2016/2017 |
| **MASTER'S DEGREE (MSC)** | PHYSICS |
| **SUBJECT** | ECONOPHYSICS |
| **TYPE OF EDUCATIONAL ACTIVITY** | C |
| **AMBIT** | 20901-Attività formative affini o integrative |
| **CODE** | 18163 |
| **SCIENTIFIC SECTOR(S)** | FIS/07 |
| **HEAD PROFESSOR(S)** | MANTEGNA ROSARIO NUNZIO Professore Ordinario Univ. di PALERMO |
| **OTHER PROFESSOR(S)** | |
| **CREDITS** | 6 |
| **INDIVIDUAL STUDY (Hrs)** | 98 |
| **COURSE ACTIVITY (Hrs)** | 52 |
| **PROPAEDEUTICAL SUBJECTS** | |
| **MUTUALIZATION** | |
| **YEAR** | 2 |
| **TERM (SEMESTER)** | 1° semester |
| **ATTENDANCE** | Not mandatory |
| **EVALUATION** | Out of 30 |
| **TEACHER OFFICE HOURS** | **MANTEGNA ROSARIO NUNZIO**<br>Tuesday 15:00 17:00 Studio del docente presso l'Edificio 18 di Viale delle Scienze previa comunicazione email all'indirizzo rosario.mantegna@unipa.it Professor's office located at Building 18 in Viale delle Scienze upon previous email agreement to rosario.mantegna@unipa.it |

**DOCENTE:** Prof. ROSARIO NUNZIO MANTEGNA

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| **PREREQUISITES** | Knowledge of mathematical methods traditionally used in the modeling of physics problems. Knowledge of a high-level computer programming language. |
| **LEARNING OUTCOMES** | Knowledge and understanding: Acquire the basic concepts of probability theory and its applications to open systems and systems not in equilibrium. Learn basic concepts of Statistics. Learn the concept of statistical test. Having mastered the basic concepts associated with stochastic variables. Learn the concept of agent based model. At the end of the course students should be able to identify those concepts of statistical physics, probability theory and computer science that are useful to perform analysis and modeling of complex systems of physical, financial, economic, social and socio-technical origin. The assessment of these skills will be carried out with periodic tests in which the student will be called to perform the analysis and modeling of some classic complex systems of economic and financial nature.<br>Applying knowledge and understanding: Ability to recognize complex systems where to carry out analysis and modeling in terms of concepts of statistical physics, probability theory and statistics. Ability to access databases of complex systems and to carry out a proper pre-processing of the same data.<br>Making judgments: Ability to assess the degree of approximation associated with a specific physical theory used in describing complex systems of economic and financial nature.<br>Communication skills: Ability to expose the key aspects of the modeling process of a complex system.<br>Learning skills: Being able to understand the physical, economic and probabilistic concepts that are at the basis of the description of complex systems of economic and financial nature. |
| **ASSESSMENT METHODS** | Final grade will be decided by considering an assignment consisting of a report on a subject agreed by the teacher with each student and an oral exam. The report should provide a short theoretical introduction to the subject, and a description of a case study observed in a real system or a simulation of a model. The oral exam consists of an examination-interview in which the candidate must demonstrate that it understand the issues and concepts presented during the course.<br>The final assessment, properly graded, will be formulated on the basis of the following conditions:<br>a) Basic knowledge of themes and concepts of Econophysics and written report on a topic carried out at a sufficient degree (18-22);<br>b) good knowledge of themes and concepts of Econophysics and written report on a topic carried out at a good degree (23-26);<br>c) detailed knowledge of themes and concepts of Econophysics and written report on a topic carried out at an excellent degree (27-30 cum laude); |
| **EDUCATIONAL OBJECTIVES** | 1) to acquire knowledge of the methodological process of statistical physics in the analysis, characterization and modeling of financial and economic complex systems.<br>2) to acquire concepts of probability theory and stochastic processes useful in the analysis and modeling of complex systems of financial and economic nature.<br>3) to introduce students to research issues by putting them in a position to properly assess the international literature on research whose purpose are complex systems of financial, economic, physical and socio-technical origin by using statistical physics concepts and methods of physical analysis and data mining procedures. |
| **TEACHING METHODS** | Teaching takes place in the first semester (September-January) of the second year of the master's degree in Physics. The teaching consists of lectures and hands-on sessions. The first is intended to provide basic knowledge of themes and concepts of Econophysics. The tutorials will familiarize you with the themes of the course and apply the studied concepts to case studies of the real world. |
| **SUGGESTED BIBLIOGRAPHY** | 1) Mantegna, Rosario Nunzio, and Harry Eugene Stanley. An introduction to Econophysics: correlations and complexity in finance. Cambridge university press, 2000.<br>2) Bouchaud, Jean-Philippe, and Marc Potters. Theory of financial risk and derivative pricing: from statistical physics to risk management. Cambridge university press, 2003.<br>3) Frantisek Slanina – Essentials of Econophysics modelling – Oxford university Press 2014. |

## SYLLABUS

| Hrs | Frontal teaching |
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| 2 | Introduction - Historical background - The introduction of the utility function by Daniel Bernoulli - The Gravity model of Jan Tinbergen - The correspondence between Walras and Poincare - The background of Econophysics - The development of Econophysics in Italy and in the world. The concept of "stylized facts" - Stylized facts in finance - Univariate and multivariate stylized facts in economics - The Brownian motion - The concept of the absence of arbitrage opportunities - The contribution of Bachelier - The first quantitative investigation of financial data and tests of econometrics - The efficient market hypothesis. |

# SYLLABUS

| Hrs | Frontal teaching |
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| 2 | The geometric Brownian motion - Stochastic processes with finite memory - The Ornstein-Ulehnbeck process - Lévy stable stochastic processes - The central limit theorem - The generalized central limit theorem - Long range correlated stochastic processes - Stochastic processes with conditional heteroskedasticity - ARCH, GARCH and FIGARCH, processes. |
| 2 | Fractal geometry - Geometric fractals - Statistical fractals - Mono-fractals and Multifractals - The physical description of the statistical multifractal - Multifractal models of the return dynamics of a financial asset. |
| 2 | Stochastic models of returns and volatility - Subordinated stochastic variables - The truncated Lévy processes - Advantages and limitations of the multifractal model. Time-invariance of a series of returns of a financial asset. |
| 2 | Derivatives - Futures and options - European and American options - The Black and Scholes model - Physics analog of the model of Black and Scholes - Limits of the Black and Scholes model. |
| 2 | The order book in main financial markets - Stylized facts of the order book. Explicit liquidity and implied liquidity - Physics models of the order book - Reaction-diffusion models - Models of order book dynamics as stochastic multiplicative processes - Microstructure of financial markets - The impact of a transaction on the price dynamics - Adverse selection - The Roll model model. Kyle model. The "zero intelligence" model - Volume weighted average price - Optimal submission of market orders. |
| 2 | The trading performed by computers (algorithmic trading) and flash crashes. Timescales of algorithmic trading. Diffusion of the practice of algorithmic trading. Fragmentation of financial markets. The flash crash of May 6, 2010. Financial market regulation. |
| 2 | Risk management and extreme events in financial markets. Statistics of extreme events. Classes of stochastic processes characterized by the same type of extreme events. Distributions of Gumbel, Weibull and Frechet. Generalized distribution of extreme events. Basin of attraction of classes of stochastic processes. Value at Risk and expected shortfall. |
| 2 | Impact of news in the pricing of an asset in a financial market. Aggregation of information due to endogenous and exogenous events in a financial market. Quality of news and sentiment conveyed in them. Automated sentiment analysis methodologies. Quarterly reports and impact on prices. |
| 2 | Correlation between pairs of return of financial assets - Portfolio Optimization - The classic Markowitz solution: (i) the case of risky assets, and (ii) risky assets with a risk-free asset. Problems related to the empirical estimation of the covariance and / or correlation matrix. |
| 2 | Principal component analysis - Classical multivariate analysis - Factor analysis - Basic concepts of the theory of random matrices - Spectral density of eigenvalues of a multivariate Gaussian random process. Eigenvalues carrying information and "noise dressed" eigenvalues. Filtering of a correlation matrix with respect to a null hypothesis. |
| 2 | Basic concepts of hierarchical clustering. The hierarchical clustering methods of single linkage, average linkage and complete linkage. The method of k-means. Hierarchical trees - Filtering a similarity matrix with hierarchical clustering methods. |
| 2 | Estimation of the covariance or correlation matrix with high frequency data. Estimation of the correlation of not synchronous time series. The Epps effect. Estimators of correlation based on Fourier transforms and methodology of Hayashi-Yoshida. The concept of course of dimensionality and the concept of shrinkage. |
| 2 | Similarity based networks - Minimum spanning tree and the Planar Maximally Filtered Graph. Networks obtained from the partial correlation coefficients. Networks obtained by using multiple statistical tests. |
| 2 | Critical phenomena - Continuous and discontinuous phase transitions - The one-dimensional and two-dimensional Ising model - Percolation - The scaling concept. |
| 2 | The minority game - Physical and economic aspects of the minority game - Inductive reasoning compared to the deductive reasoning - The order parameter in the minority game - Characterization of the different phases in the minority game. |
| 2 | The concept of complex network. The Erdos-Renyi model (random networks) - The distribution of the degree of a random network - The distribution of degree of a scale free network - Six Degrees of Separation - Small world networks - Scale free networks - The Barabasi-Albert model. |
| 2 | Complex networks in physical, economic, social, and socio-technical systems. Metrics for analysis and modeling of complex networks - Coefficient of local and global clustering - Betwenness - k-motifs - Analysis of k-motifs - the "community" concept in complex networks - Systemic risk - The 2007-2008 crisis. Systemic risk models based on complex networks. DebtRank. The interbank market. The maximum entropy method. |
| 2 | Power laws in complex systems. Zipf's law in linguistics, economics and biology. Gibrat's law in complex systems. Models for Zipf's law. Gibrat's law and stochastic multiplicative processes. Power-laws in dynamical processes: The Omori's law. |
| 2 | Agent based models. Agent based models in the generation of time dependent complex networks. agent to models for the generation of complex networks. Agent based models in finance. Agent based models in macroeconomics. |

| Hrs | Practice |
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| 2 | Tutorial on quantitative test on the efficient market hypothesis. |
| 2 | Tutorial on the pricing of futures and European options. |
| 2 | Tutorial on the analysis and modeling of extreme events. |
| 2 | Tutorial on Principal Component Analysis and Random Matrix Theory. |
| 2 | Tutorial on hierarchical clustering methods, and on similarity based networks. |

| Hrs | Practice |
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| 2 | Tutorial on the analysis and modeling of complex networks. |