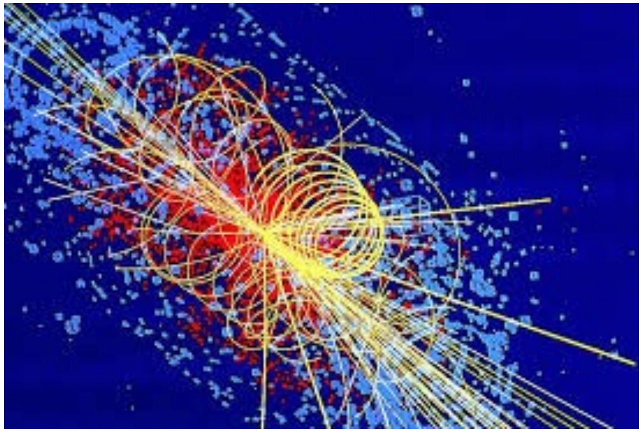

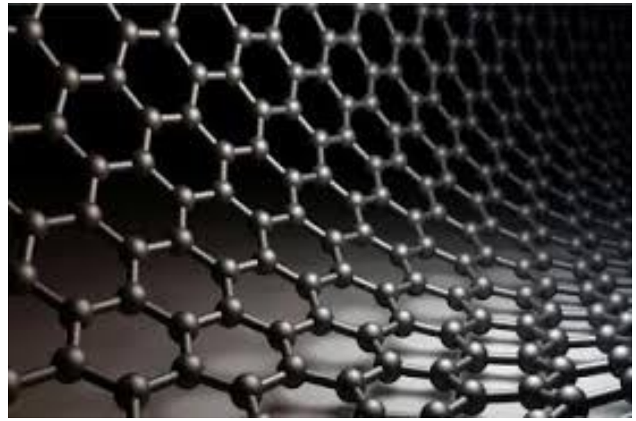

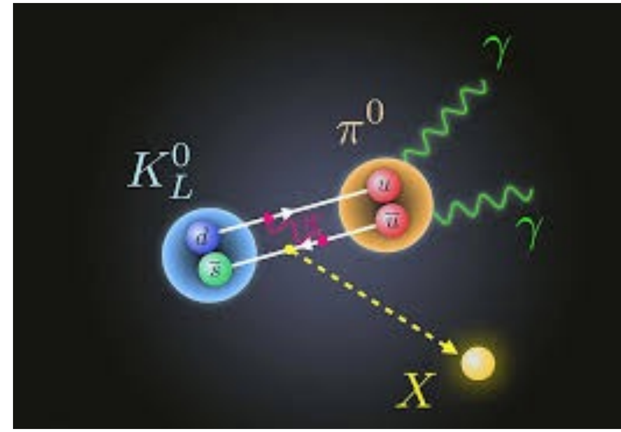

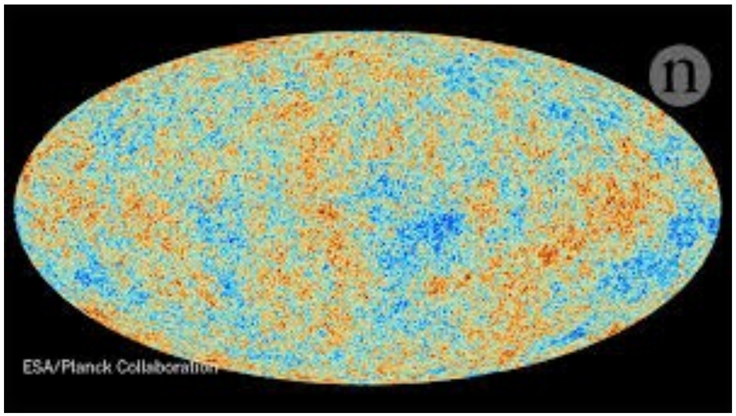

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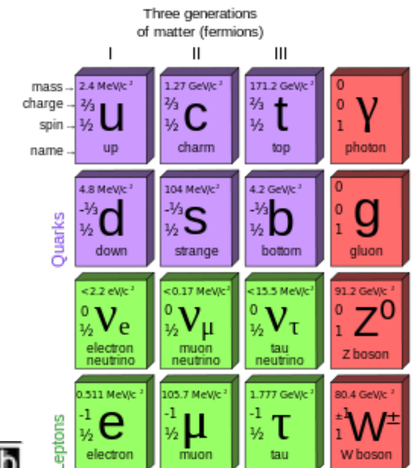

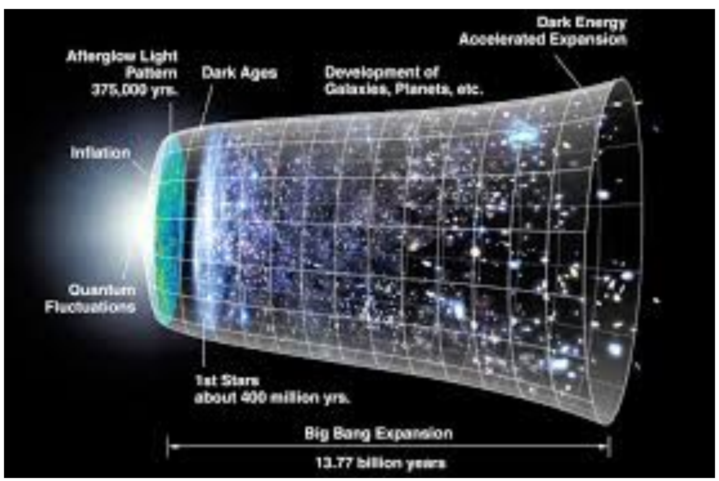

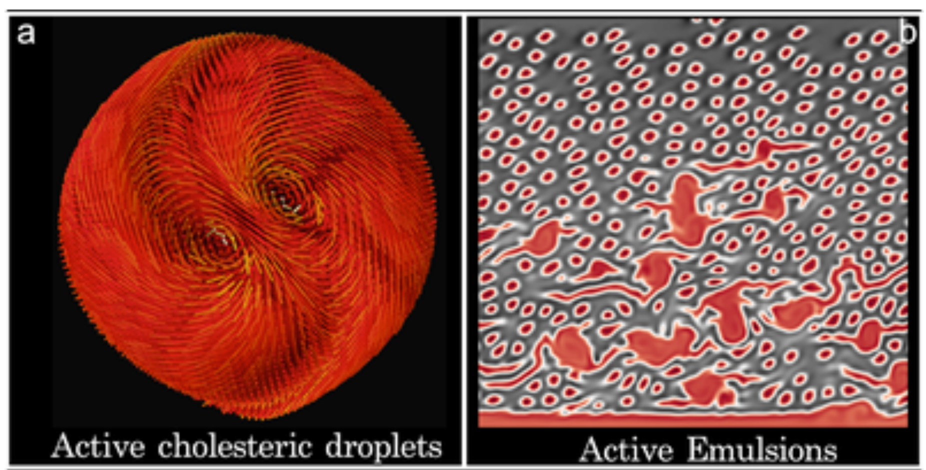

SUPRA
(Southern Universities Physics Research Agreement)

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I. Particle Detectors–Trigger/DAQ

Module 1	**Particle Detectors**
Lecturer	Margherita Primavera (INFN Lecce)
Planned hours	22
Planned schedule	
Prerequisites	Charged particles interactions with matter
Description	Generalities on gaseous detectors. Ionization and transport phenomena in gases. Amplification in gases. Gaseous detectors: ionization chambers, proportional counters, MultiWire Proportional Chambers, Drift chambers, TPC, Geiger counters, streamer tubes, Resistive Plate Counters. Calorimetry. Electromagnetic and hadronic calorimeters. Calorimeter calibration and monitoring. Cherenkov detectors: DISC, RICH, DIRC. Transition radiation detectors. Micropattern detectors, dual readout calorimeters.

Module 2	**Photodetection**
Lecturer	Elisabetta Bissaldi (Politecnico di Bari)
Planned hours	16
Planned schedule	1 lecture per week two hours each
Prerequisites	Experimental particle physics background
Description	This course aims to provide the student with advanced knowledge of radiation measurements and detection techniques, from classic scintillation detectors to Silicon Photomultiplier devices. It requires an elementary background in radiation measurements, radiation matter interactions and basic electronics. The program includes Photon-matter interactions; Organic and Inorganic scintillators; Optical coupling; Solid-state photodetectors; SiPM technologies, properties and Applications.Part of the course will be devoted to laboratory sessions.

Module 3	**Trigger and DAQ for Particle Physics**
Lecturer	Massimo Della Pietra (Univ. Federico II NAPOLI)
Planned hours	10
Planned schedule	
Prerequisites	Experimental particle physics background
Description	Introduction to trigger and data acquisition system for experimental physics. Basic elements and definitions: trigger latency and trigger rate. Connection between trigger e data acquisition: dead time and busy status. Multilevel trigger systems, trigger for High Energy Physics at colliders. Integration of Trigger - DAQ and related systems Event building, Run Control, Online data quality. Description of most relevant trigger system for collider HEP: the trigger system of the LHC experiments. Trigger systems for fixed target experiments and for test-beam setup. Triggerless DAQ systems for particle and astroparticle physics. The impact of the trigger system efficiency on a physical measurement.

II. Signals Formation and Treatment in Particle Detectors

Module 1	Signals Formation
Lecturer	Marcello Abbrescia (uniba)
Planned hours	10
Planned schedule	5 lectures of 2 hours each
Prerequisites	Basic notions of electromagnetism and of particle detector physics
Description	- Electrostatics-Principles-Reciprocity-Induced currents-Induced voltages-Ramo-Shockley theorem-Mean value theorem- Capacitance matrix-Equivalent circuits; - Signals in: -Ionization chambers-Liquid argon calorimeters-Diamond detectors-Silicon detectors-GEMs (Gas Electron Multiplier) -Micromegas (Micromesh gas detector) -APDs (Avalanche Photo Diodes)-LGADs (Low Gain Avalanche Diodes)- SiPMs(Silicon Photo Multipliers) -Strip detectors-Pixel detectors- Wire Chambers -Liquid Argon TPCs.

Module 2	Signals Treatment
Lecturer	Alberto Aloisio (unina)
Planned hours	10
Planned schedule	
Prerequisites	
Description	Sistemi di schermatura e di guardia nella lettura di sensori e rivelatori - Cenni sul noise di componenti attivi e passivi - Uso del simulatore analogico per l'analisi di alcuni casi di studio: rumore di alcune configurazioni base degli amplificatori operazionali, effetto della capacità del rivelatore sul noise gain

III. Multi-Messenger and Particle Astrophysics of Compact Objects

Module 1	Compact Objects
Lecturer	Francesco De Paolis (Università del Salento)
Planned hours	6
Planned schedule	
Prerequisites	Basic Astrophysics
Description	• Last stages of stellar evolution and formation of the compact objects • Phenomenological properties of neutron stars and pulsars Selected recent topics on the physics of the compact objects
Recommended texts	• Slides of the lecturer and texts suggested during the lectures
Assessment methods	Short essay on one of the topics developed during the lectures

Module 2	Neutrino Oscillations
Lecturer	Daniele Montanino (Università del Salento)
Planned hours	6-8
Planned schedule	
Prerequisites	Particle physics
Description	• Introduction to the neutrino masses, mixing and oscillations in vacuum and matter • Phenomenology of neutrino oscillations from terrestrial experiments and astrophysical sources, in particular solar neutrinos
Recommended texts	• Giunti, Kim, “Fundamentals of neutrino Physics and Astrophysics” (Oxford University Press, 2007) • Slides of the lecturer
Assessment methods	Short essay on one of the topics developed during the lectures

Module 3	Supernova Neutrinos
Lecturer	Alessandro Mirizzi (Università di Bari)
Planned hours	6
Planned schedule	
Prerequisites	Particle physics
Description	• Supernova (SN) explosion mechanism • SN 1987A neutrino observation • Future SN neutrino observations • Neutrino oscillations in dense SN medium
Recommended texts	• G. Raffelt, “Stars as Laboratories for Fundamental Physics” (University of Chicago Press, 1996) • Slides of the lectures
Assessment methods	Short essay on one of the topics developed during the lectures

Module 4	Gravitation, Relativity and Black Holes
Lecturer	Mariafelicia De Laurentis (Università di Napoli)
Planned hours	6-8
Planned schedule	
Prerequisites	analytical mechanics, general relativity
Description	Rotating black holes: Kerr Spacetime and its global properties. Kerr black hole in Boyer-Lindquist coordinates. Zero-mass limit. Kerr-Schild form of the Kerr solution. Ergosphere and Horizon (Infinite redshift surface, Surface gravity, Surface geometry of horizon and ergo surface) Particle and Light Motion in Equatorial Plane. Matter accretion and black hole parameters change. Evolution in the black hole parameter space. Geodesics in Kerr Spacetime: General Case. Light Propagation. Black hole shadow. Generic properties of the rotating black hole shadows (Asymmetry, Flattening etc..). Image of Black Holes with the Event Horizon Telescope.
Recommended texts	Slides of the lectures
Assessment methods	Short essay on one of the topics developed during the lectures

Module 5	Physics and Evolution of Supermassive Black Holes
Lecturer	Maurizio Paolillo (Università di Napoli)
Planned hours	6-8
Planned schedule	
Prerequisites	Basic classical physics and gravitation. Useful but not required: Module "Gravitation, Relativity and Black Holes", Introductory astrophysics, Physics of Galaxies
Description	The Discovery of Active Galactic Nuclei; Taxonomy of AGNs; clues to the interpretation: variability, luminosity and efficiency; steps toward unification: Eddington luminosity, Eddington mass and accretion rate; accretion efficiency. The Unified Model; AGN physical scales; broadband emission in AGNs; accretion disk spectrum; X-ray corona and other components. Observational evidence of the Unified Model: Quasar host galaxies; dynamical and reverberation mapping mass measurements; evidence of hidden BLR in Sy2; relativistic distortion in Fe lines; the Milky Way nuclear BH. AGN evolution from multi-wavelength studies of AGN populations optical, X-ray and infrared; luminosity function and number counts; AGN activity and number density evolution; resolving the Cosmic X-ray Background; Soltan argument: how to derive the current Black Hole mass density of the Universe; The link between Supermassive Black Holes and galaxy evolution; Evidences of AGN feedback in galaxies.
Recommended texts	Lecture slides; "Exploring the X-ray Universe", Seward & Charles,2010)
Assessment methods	Short essay on one of the topics developed during the lectures

Module 6	Gravitational waves and Gamma-Ray Bursts
Lecturer	Tristano Di Girolamo (Università di Napoli)
Planned hours	6-8
Planned schedule	
Prerequisites	Basic astrophysics and particle physics
Description	Generation of Gravitational Waves (GWs). Binary Black Holes (BBHs) as sources of GWs. Detection of GWs. Observations of GWs from BBHs. Gamma Ray Bursts (GRBs): observations and theoretical models. GRB progenitors. Black holes as central engines and final products of GRBs.
Recommended texts	Shapiro & Teukolsky, "Black Holes, White Dwarfs and Neutron Stars"
Assessment methods	Short essay on one of the topics developed during the lectures

IV. Fundamental Interaction: QCD and BSM

Module 1	Perturbative QCD
Lecturer	Francesco Tramontano (NAPOLI)
Planned hours	12
Planned schedule	2 lectures per week two hours each
Prerequisites	Particle physics background
Description	The lectures introduce to some basic aspects and concepts of perturbative QCD: running coupling and asymptotic freedom, the parton model, infrared divergences and the factorization theorem, parton densities and parton evolution, colour coherence. Applications to e+e-annihilation, deep inelastic lepton-nucleon scattering and hadron-hadron collisions are discussed.

Module 2	Teoria di Regge
Lecturer	Giovanni Chirilli (Regensburg) ref. Claudio Corianò
Planned hours	10
Planned schedule	
Prerequisites	Particle physics background
Description	Regge Theory; High parton density; small x evolution equations and Wilson lines formalism; Background field method; High-energy Operator Product Expansion; High-energy factorization for scattering amplitudes;

Module 3	BSM
Lecturer	Fulvia De Fazio (BARI)
Planned hours	16
Planned schedule	
Prerequisites	Particle physics background
Description	Physics beyond the Standard Model- Reasons to go beyond the Standard Model- Models based on extended gauge groups- Models introducing extra dimensions- Aspects of supersymmetry- Extension of the effective hamiltonians in New Physics Models

V. Artificial Intelligence and Machine learning

Module 1	Data Modelling
Lecturer	Nicola Amoroso (UniBA)
Planned hours	10
Planned schedule	
Prerequisites	
Description	Introduction: graph theory. Different graph models. Nodal and edge characterization. Local and global properties. Community detection. Learning: Basic definitions, bias, variance and cross-validation. Supervised Models. Deep Learning. Unsupervised models: Clustering.

Module 2	Machine Learning: Basis and Applications
Lecturer	Giorgio De Nunzio & Giuseppe Palma
Planned hours	10
Planned schedule	
Prerequisites	
Description	ML taxonomy: supervised, reinforcement, unsupervised; Regression: linear regression, GLM. Classification: scores (confusion matrix and related measures; ROC curve; calibration; cross entropy, Brier score), class imbalance. Bias-Variance tradeoff: underfitting, overfitting. Perceptrons and Shallow Feed-Forward Neural Networks. Applications of regression and classification: case studies in Physics and Medicine with synthetic and public access data (python).

Module 3	Causality Analysis of Time Series Data
Lecturer	Sebastiano Stramaglia (UniBA)
Planned hours	10
Planned schedule	
Prerequisites	
Description	• Complex Networks. Small world networks: Watts-Strogatz model. Scale free networks: Albert-Barabasi model. Communities in complex networks. Applications. • The problem of inference of Complex Networks from multivariate time series data. Time Series. Stationarity. Linear correlations and the power spectrum. Cross-correlation and coherence between time series. Prediction. Applications. • Introduction to Information Theory. Shannon’s Entropy. Mutual Information. Maximum Entropy methods. Transfer Entropy. Applications. • Vector autoregressive models. Granger causality and its relation with transfer entropy. Applications. • Decomposition of Granger causality in frequency and time. Higher order dynamical networks. Synergy and redundancy. Applications.

VI. Quantum Information and Quantum Technologies

Module 1	Physical Coherence and Correlation Functions
Lecturer	Saverio Pascazio (UniBA)
Planned hours	16
Planned schedule	Eight two-hour lectures
Prerequisites	Background in quantum theory, technologies and applications
Description	Optical Fluctuations and Coherence. Classical and Quantum theory. The Radiation field. Experimental milestones. Measuring correlation functions. Equilibrium equal-time (spatial) correlation functions Equilibrium equal-position (temporal) correlation functions. Beyond equilibrium. Phase transitions and correlation functions.

Module 2	Introduction to Quantum Computation
Lecturer	Luigi Martina (UniSalento)
Planned hours	16
Planned schedule	Eight two-hour lectures
Prerequisites	Quantum Mechanics and Statistical Mechanics
Description	Since at least a couple of decades, the Physics of Information and Computation has been a recognized as an autonomous discipline. In fact, the latter fields should be linked to the study of the underlying physical processes, namely of the quantum mechanical universe. But the intrinsic probabilistic character of the quantum measurements and the non-commutative algebra of the observables induce important modifications in the central results of classical information theory, including: quantum parallelism, compression of quantum information, bounds on classical information encoded in quantum systems, bounds on quantum information sent over a noisy quantum channel, efficient quantum algorithms and quantum complexity. The course will touch the above topics.

Module 3	Quantum imaging
Lecturer	Milena D’Angelo (UniBA) Cosmo Lupo (PoliBa)
Planned hours	16
Planned schedule	Eight two-hour lectures
Prerequisites	Background in quantum theory and optics. Attendance of either one of the two above modules is suggested.
Description	From classical to quantum imaging. Klyshko advanced wave model. Ghost imaging and diffraction, from first protocols to recent advances (differential GI, computational GI, compressive GI,..). Single-pixel imaging. Super-resolution: NOON states, and Quantum Fisher information. Sub-shot-noise imaging. Imaging by undetected photons. Imaging through turbulence and scattering media, and imaging around corners. Correlation plenoptic imaging: from principles to applications.

VII. Experimental High-Energy Astroparticle Physics

Module 1	Experimental Techniques in Astroparticle Physics
Lecturer	Giovanni Marsella (Palermo)
Planned hours	16
Planned schedule	
Prerequisites	Basic particle physics, astrophysics and detectors
Description	Description of the principal experimental techniques in Astroparticle Physics Contents: • Introduction to Cosmic Ray (CR) sources • Primary CRs, acceleration mechanism, propagation • Secondary CRs, atmospheric showers • Detection techniques in Space, Extensive Air Shower arrays and underground detectors • Presentation of the principal experiments and recent results
Recommended texts	
Assessment methods	

Module 2	HE and VHE Observations from Extragalatics Sources
Lecturer	Lorenzo Perrone et al. (Lecce)
Planned hours	5-10
Planned schedule	
Prerequisites	Basic particle physics, astrophysics and detectors
Description	The lectures intend to cover the description of the detection techniques of ultra-high energy cosmic rays (Pierre Auger Observatory, Telescope Array) and the current status of the art (result and perspectives) in the field.
Recommended texts	Review papers and journal papers.
Assessment methods	Lessons, final report, hands-on session

Module 3	HE Transients and the Multimessenger Context
Lecturer	Elisabetta Bissaldi (Politecnico di Bari)
Planned hours	16
Planned schedule	
Prerequisites	Basic astrophysics, Detectors
Description	- Transient phenomena in the gamma-ray sky: Gamma-Ray Bursts (GRBs), Soft Gamma Repeaters, Terrestrial Gamma-Ray Flashes; Solar Flares. Temporal and spectral characteristics; - Multi-frequency and Multi-messenger studies; LIGO/Virgo gravitational wave (GW) events and follow-up observations; The case of GRB 170817A / GW 170817; IceCube neutrino events and follow-up observations; The case of TXS 0506+056; Other recent discoveries in the field.
Recommended texts	1. Longair - “High-energy astrophysics” 2. De Angelis & Pimenta - “Introduction to Particle and Astroparticle Physics” 3. Recent Publications
Assessment methods	Lessons, final report

Module 4	Indirect Dark Matter Searches
Lecturer	Francesco Loparco (Bari)
Planned hours	16
Planned schedule	
Prerequisites	Basic particle physics and detectors
Description	1) Dark Matter models 2) Dark matter distribution in galaxies 3) WIMPs as dark matter candidates 4) Indirect dark matter searches with gamma rays and charged particles 5) Searches dark matter from the Sun
Recommended texts	Recent publications, some textbooks, slides from the lecturer
Assessment methods	Final report

VIII. Statistical Physics for Complex Systems

Module 1	Active Matter and Complex Fluids
Lecturer	Giuseppe Gonnella (UniBA) – Antonio Lamura (CNR-Bari)
Planned hours	16
Planned schedule	Eight two-hour lectures
Prerequisites	Background in classical physics and statistical mechanics
Goal	The purpose of these lectures is to give an introductory overview to recent research developments in the field of applications of statistical and theoretical physics to complex fluids, soft matter and biological systems.
Description	Statistical physics and biological systems. Active matter: basic particle and continuous models. The phase diagram of passive and active colloids. Topological transitions. Complex fluids: theoretical modeling. Polymers: static and dynamical properties in dilute conditions. Ternary mixtures with surfactant: self-aggregation, active and double emulsions. Basic rheological behavior of complex fluids. The yielding transition. Simulations methods in soft and active matter. Molecular dynamics, Multi-Particle Collison Methods, Lattice Boltzmann Methods.

Module 2	Statistical Mechanics of Complex Systems
Lecturer	Antonio De Candia (UniNa Federico II)
Planned hours	16
Planned schedule	Eight two-hour lectures
Prerequisites	Basic knowledge of statistical mechanics.
Goal	The purpose of these lectures is to introduce basic concepts in the physics of complexity, as they emerge in the context of disordered systems.
Description	The Sherrington - Kirkpatrick model for spin glasses. Replica - symmetric solution. The Parisi solution. The p - spin model. The cavity method. Dynamics and Mode - Coupling theory. TAP equations. The spin - glass on the Bethe lattice.

Module 3	**Stochastic Processes and Analysis of Correlations**
Lecturer	Eugenio Lippiello (University of Campania "Luigi Vanvitelli")
Planned hours	16
Planned schedule	Eight two-hour lectures
Prerequisites	Background in classical statistical mechanics.
Goal	The purpose of these lectures is to give a simple mathematical introduction to the description of stochastic processes with innovative applications in the field of epidemiology and earthquake data time- series analysis.
Description	Markov processes. Master and Fokker Plank equations. Stochastic energetics. Branching processes. Watson-Galton model. Application to genetics. Epidemic models. Applications to epidemiology and earthquake occurrence. Analysis of correlations in stochastic signals. Detrended Fluctuation Analysis. Power spectrum of a signal.

IX. Biophysics for Health and Environment

Module 1	Biophysical mechanisms and therapeutic implications of human exposure to ionising radiation
Lecturer	Lorenzo Manti (Università Federico II Napoli)
Planned hours	20
Planned schedule	10 lectures of 2 hours each
Prerequisites	Fundamentals of radiation-matter interaction
Description	The aim of the course is to provide an overview of the unique biological action exerted by ionizing radiation (IR). The ensuing effects at cellular and tissue level are governed by the spatio-temporal mode with which energy deposition occurs at the nanometer level (i.e., at the scale of the DNA) and are influenced by a cascade of complex biomolecular responses. The course will therefore illustrate the main biophysical principles on which modern radiotherapy (RT) relies. New approaches will be also discussed such as the use of accelerated particle beams (hadrontherapy) and the exploitation of nuclear fusion reactions where physics can give an essential contribution to IR-based cancer therapy

Module 2	Biophotonics for clinics and environment
Lecturer	Maria Lepore (Università della Campania «Luigi Vanvitelli»)
Planned hours	24
Planned schedule	
Prerequisites	Basic concepts of optical techniques
Description	The course will deal with the application of optical techniques to the development of new diagnostic strategies and environment monitoring tools. Vibrational and fluorescence spectroscopies will be used for investigating biofluids, human tissues, radioexposed cells and enzymes in order to monitor biological processes and to develop sensor devices.

Module 3	Numerical Methods for Data Analysis in Optical Spectroscopy
Lecturer	I. Delfino (Università della Tuscia) - C. Camerlingo (SPIN-CNR) - M. Lepore (Università della Campania «Luigi Vanvitelli»)
Planned hours	18
Planned schedule	
Prerequisites	Basic notions of a programming language
Description	The course aims to introduce numerical methods particularly useful for the analysis of spectral data with particular attention to background subtraction, noise reduction and quantitative applications (chemometrics). Univariate and multivariate analysis (PCA, Principal Component Analysis), wavelet algorithms will be discussed and applied in the analysis of practical cases of students’ interest.