Programs of the courses – Roma Tor Vergata – academic year 2017-2018

semester S3 Edition 7

compulsory courses

Astrophysics Laboratory *(Dr. L. Giovannelli)*
Elements of applied optics: real systems, calculation of the achromatic doublet, lens systems. Telescopes and focal plane instruments: main optical schemes, coronagraphs, mounts, derotators, imaging spectrometers. Outline of X-ray, Gamma-ray and radioastronomy optics. Photometry: filters, photometric systems, color index, distance modulus, distance, color correction. Detectors: calibration of photographic plates, CCD, CMOS, Hybrid. Cryogenic systems for IR. Monitoring and sampling electronics. Calibration techniques (PHT).Science communications: How to write a scientifica paper; Preparing a scientific talk, writing a poster. Laboratory practice: sensors: calibration of a CCD (linearity and Photon Transfer technique). Solar Center-to Limb Darkening; The Michelson Interferometer; Data analisys and data reduction of a X-ray telescope
Compulsory, 8 ECTS

Relativity and Cosmology 2 *(Prof. N. Vittorio)*
Equation of instabilities in the newtonian limit. Jeans wavelength. Diffusion and free-streaming phenomena. Correlation function and power spectrum of density fluctuations. Gaussian statistic and initial conditions. Evolution of the power spectrum in cosmological models. Galaxy correlation function. Dipole anisotropy of the cosmic background and the "great attractor". Intensity and polarization anisotropies of the cosmic background. Sachs-Wolfe effect. Results from satellites (COBE and WMAP) and balloons (BOOMERANG, MAXIMA, B2K). Redshift Surveys.
Compulsory, 6 ECTS

optional courses

Astrobiology *(Prof. A. Balbi, Prof. D. Billi)*
Introduction to astrobiology. The Universe and the cosmic environment. Formation of chemical elements. Star formation and hypotheses on the origin of planetary systems. Requirements for life as we know it. Prebiotic chemistry, molecular evolution, and cellular life. Extremophiles and the search of life on other planets. Space as an extreme environment. Experiments in Low Earth Orbit (Expose e Biopan). Lithopanspermia. Search for life outside of the Solar System. Extrasolar planets. SETI.
Optional, 6 ECTS

Gravitational Lensing *(Prof. P. Mazzotta)*
Large scale structure of the Universe. Formation and dynamics of the cosmic web, of clusters and groups of galaxies. simple collapse models for the dark matter. Physics of intergalactic and intracluster gas. Heating and cooling mechanisms. Chemical enrichment of intergalactic and intracluster gas. Observations of clusters of galaxies in X-ray and microwave bands, Lyalpha and Xray-forest. Estimate of the mass of clusters of galaxies: dynamical methods, observations in Xray and microwave bands, gravitational lenses. Cosmology with clusters of galaxies: mass function, scaling laws.
Optional, 6 ECTS

Gravitational Waves *(Prof. V. Fafone)*
Review of general relativity and of metric theories of gravitation: observable quantities. Astrophysical sources of gravitational waves, waveshapes and information obtainable experimentally. Stocastic background. Ground-based and space detectors. Experimental techniques used in resonant detectors and in interferometric detectors.
Optional, 6 ECTS

High Energy Astrophysics *(Prof. G. Tavani – Prof. G. Israel)*
Introduction: history of X-ray and Gamma-ray astronomy; collimated vs. imaging instruments, angular, spectral and time resolution. Basics: emission mechanisms; degenerate stars (white dwarfs and neutron stars); black holes; accretion theory. Compact X-ray and Gamma ray sources: radio pulsars, X-ray binaries, isolated compact objects, magnetars. Brief introduction to high energy emission from non-degenerate stars, supernova remnants and galaxies of the local group. Gamma ray bursts.
Optional, 6 ECTS

Stellar Populations *(Prof. G. Bono)*
1. THE DISCOVERY OF STELLAR POPULATIONS 1.1 Baade and the discovery of Galactic stellar populations 1.2 Kinematic and spectroscopic evidence 1.3 Oort's Constants, and the Rotation of the Galaxy 2. FORMATION AND EVOLUTION OF THE GALAXY 2.1 Galaxy formation: semi-analytic models 2.2 Galaxy formation: numerical simulations 2.3 Dark matter and baryonic components 3. THE COSMOLOGICAL ABUNDANCES OF THE ELEMENTS 3.1 The Big Bang nucleosynthesis 3.2 Primordial helium content 3.3 Primordial lithium content 4. STAR FORMATION 4.1 Theory and observations 4.2 Population III stars 4.3 Initial mass function 4.4 Mass luminosity relation 5. GALACTIC COMPONENTS 5.1 The halo 5.2 The thin and the thick disk 5.3 The bulge 5.4 The center 6. STELLAR SYSTEMS 6.1 Open clusters and associations 6.2 Globular clusters 6.3 Abundance patterns and anticorrelations 7. STELLAR POPULATIONS IN LOCAL GROUP GALAXIES 7.1 Andromeda group 7.2 Dwarf irregulars 7.3 Dwarf spheroidals 8. STELLAR POPULATIONS IN LOCAL VOLUME GALAXIES 8.1 Virgo cluster 8.2 Ultra compact dwarfs 8.3 Dwarf ellipticals 8.4 Ellipticals 8.5 Galaxy bulges 9. UNRESOLVED STELLAR POPULATIONS 9.1 Population synthesis 9.2 Integrated spectra and colours 10. GALACTIC CHEMICAL EVOLUTION 10.1 Star Formation rate and SN rate 10.2 Stellar abundance gradients 10.3 Gas abundance gradients 10.4 alpha-element abundances 10.5 s and r-process elements 10.6 neutron capture elements
Optional, 6 ECTS

Radiative Processes in Astrophysics *(Prof. P. Mazzotta)*
Fundamentals of radiative transfer. The electromagnetic spectrum. Radiative flux. The specific intensity and its momentum. Radiative transfer. Thermal radiation. The Einstein Coefficients. Scattering effects. Radiative Diffusion. Review of Maxwell's Equations. Plane electromagnetic waves. The radiation spectrum. Polarization and Stokes parameters. Electromagnetic potentials. Radiation from moving charges. Retarded potentials of single moving charges: the Lienard-Wiechart potentials. The velocity and radiation fields. Radiation from non-relativistic systems of particles. Thomson scattering. Radiation Reaction. Radiation from harmonically bound particles. Relativistic covariance and kinematics. Review of Lorentz transformations. Four-Vectors. Tensor analysis. Covariance of electromagnetic phenomena. Fields of uniformly moving charge. Relativistic mechanics and the Lorentz four-force. Emission from relativistic particles. Bremsstrahlung. Emission from single speed electron. Thermal Bremsstrahlung emission. Thermal Bremsstrahlung absorption. Relativistic Bremsstrahlung. Synchrotron radiation. Total emitted power. Spectrum of synchrotron radiation. Spectral index fro power-law electron distribution. Polarization of synchrotron radiation emission. Synchrotron self-

absorption. Compton scattering. Cross section and energy transfer for the fundamental process. Inverse Compton power for single scattering. Inverse Compton spectra for single scattering. Energy transfer for repeated scattering in a finite, thermal medium: the Compton y parameter. Inverse Compton spectra and power for repeated scattering by relativistic electron of small optical depth. Repeated scattering by non-relativistic electrons: the Kompaneets equation. The Sunyaev-Zeldovich effect.
Optional, 6 ECTS

Extragalactic Astrophysics *(Prof. F. Vagnetti)*
The Galaxy and the galaxies, main data, classification, catalogs, surface photometry, luminosity function. Rotation curve of the Milky Way, dark matter. Disk galaxies, photometry, rotation curves, Tully-Fisher relation. Elliptical galaxies, photometry, stellar velocities, Faber-Jackson relation, fundamental plane. Active galactic nuclei, black hole paradigm, accretion disk. Continuous emission and variability. Spectral energy distribution. Taxonomy, unified schemes. Tidal disruptions. X-ray/UV ratio. Relativistic effects, superluminal motion, blazars. Broad line region and narrow line region. Reverberation mapping. cloud properties, line-continuous correlations, Baldwin effect. Size-luminosity relations. Cosmological framework, luminosity distance, look-back time. Surveys, Eddington effect, K-correction. Selection criteria. logN-logS and V/Vmax test. Luminosity function and its evolution. Cosmic Downsizing. Quasar-galaxy coevolution. Black hole growth by accretion and merging. Intergalactic absorption lines. High redshift galaxies, active and passive evolution. Color bimodality, blue cloud, red sequence.
Compulsory, 6 ECTS

Italian as a foreign language
Optional, 3 ECTS

Programs of the courses – Roma Tor Vergata – academic year 2017-2018

semester S2 Edition 8

compulsory courses

Gravitational Physics *(Prof. A. Rocchi)*
Experimental fundamentals of gravitational physics. Newton force. Principle of Equivalence of gravitation and inertia. Isotropy and homogeneity of space and time. Gravitational redshift. Principle of Equivalence in General Relativity. Lorentz invariance: measurement of g-2. Theoretical consequences and experimental verification of constancy of G in time. Classical tests of General Relativity. Theories of gravitation: predictions and experimental tests. PPN formalism. Metric and non-metric gravitational theories. Brans-Dicke theory. Parameters measured in space and ground experiments. Deviation of light. Radar echo delay. Long Baseline Interferometry. Lunar Ranging Experiment. Gravito-magnetic effect. Gravitational waves. Main methods of detection. Frontiers of gravitation. Final stages of stellar evolution. Gravitational collapse and its messengers. Emission and detection of neutrinos from supernovae and from violent astrophysical events. Predictions and experimental verification of the nature of the black holes. Detection of the stochastic background of gravitational waves. Gravity at large distances: experimental tests and theoretical interest. Gravity at short distances: experimental tests and theoretical interest.
Compulsory, 6 ECTS

Relativity and Cosmology I *(Prof. N. Vittorio)*
Fundamentals of general relativity and gravitational physics. Schwarzschild solution. Gravitational collapse. Black holes. Gravitational waves. Cosmic geometry, kinematics and dynamics, FRW models. Black body and thermodynamic equilibrium. Cosmic radiation background. Primordial nucleosynthesis.
Compulsory, 6 ECTS

Stellar Astrophysics *(Prof. G. Bono)*
Structure of the Galactic spheroid. Galactic halo. Galactic bulge. Galactic disc. Stellar systems. Globular Clusters. Open Clusters and Associations. Galactic distance scale. Metallicity distribution. Kinematic properties. Particles and Big Bang Nucleosynthesis. Nuclear evolution and α-elements. Equations of Stellar

Structure. Hydrostatic equilibrium. Schwarzschild criterion. Overshooting. Radiative and convective energy transport. Stellar atmosphere. Physical conditions of the Stellar Matter. Equation of state. Opacity and matter-radiation interaction. Energy generation. Nuclear reactions.Star formation. Star formation and evolution along the Hayashi track. Fully convective stars. Evolution until hydrogen burning ignition. The Hydrogen Burning Phase. The p-p chain. The CNO cycle. Secondary elements. The H-burning phase in Low Mass (LM) stars: the solar case. The H-burning phase in upper Main Sequence (MS) stars. The MS dependence on chemical composition and on convection efficiency. The Mass-Luminosity relation. The Schönberg-Chandrasekhar limit. Post MS evolution. Low, intermediate and massive stars. The Helium flash. The Red Giant Branch (RGB) dependence on physical and chemical parameters. The RGB bump. The tip of the RGB. Evolutionary properties of very metal-poor stars. The Helium burning phase. The nuclear reactions. The Zero Age Horizonthal Branch (ZAHB). The He core burning phase in low-mass stars. The He burning phase in more massive stars. Pulsation properties inside the Cepheid instability strip. The Advanced Evolutionary Phases. The Asymptotic Giant Branch (AGB). The thermally pulsing phase. The s-elements nucleosynthesis. Chandrasekhar limit. Carbon-Oxygen and Helium core white dwarfs. Advanced evolutionary stages. Supernovae explosions. Stellar observables of cosmological interest. Primordial Helium abundance. Absolute and relative ages of Globular Clusters. Primary and secondary distance indicators. The Hubble constant. Nucleosynthesis. Yields from AGB stars. Yields from Supernovae type Ia and type II.
Compulsory, 6 ECTS

optional courses

Astroparticle Physics *(Prof. R. Bernabei)*
Summary on the fundamental interactions between particles, waves and particles, fundamental fields, Standard Model of particles. Historical remarks. Phenomenology of the cosmic rays. Energy spectrum, composition, galactic and extragalactic origin. Mechanisms of production and of acceleration. Very high energy cosmic rays. GZK effect. Experimental situation. Energetic considerations and possible sources. Gamma rays. Detection techniques. The asymmetry of the Universe. Neutrino astronomy. Nucleosynthesis and cosmological neutrinos. Neutrinos from astrophysical sources. The Big Bang and the Dark Matter (DM) of the Universe. Role of the DM. Nature of the DM. Hints and experimental signals. Gravitational waves and detection techniques.
Optional, 6 ECTS

Celestial Mechanics *(Prof. G. Pucacco)*
Review of hamiltonian mechanics. Integrability, first integrals, simmetries. Non-

integrability, instability, chaos. Analytical and numerical methods for the study of hamiltonian dynamical systems. Two-body problem. Three-body problem. N-body problem. Motion in assigned potentials.
Optional, 6 ECTS

Sun and Space Climate *(Prof. F. Berrilli)*
Internal structure of quiet Sun, nuclear reactions and the problem of neutrinos. Heliosismology, tachoclines and solar dynamo. Turbulent convection in the Sun: new paradigm. The solar surface: quiet and active Sun. The solar spectrum: formation of spectral lines. photospheric and chromospheric dynamics. From chromosphere to solar corona: the problem of coronal heating. Flares and coronal mass emissions (CME). Solar irradiance, its spectral and temporal variability and the Earth climate.
Optional, 6 ECTS

Italian as a foreign language
Optional, 3 ECTS