Programs of courses - semester S3 - Roma Tor Vergata

compulsory courses

Relativity and Cosmology 2

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.

Physics of Gravitation

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.

optional courses

Astronomical Archives

Historical notes on the creation of the first astronomical archives, multi-band data. Archiving of astronomical data: international data standards (FITS format). Archive content: images, energy spectra, light curves. Management and

archiving of astronomical data: the structure of programs and databases. Access and use of astronomical archives: web interface, specific query examples, main tools. Astronomical data centers: survey of main centers (Simbad, NED, HEASARC, Sloan Digital Sky Survey, CDS, Vizier, ASDC, ...), contents of the archives and access to the data. Interactive tools of scientific analysis of astronomical data and comparison of multi-band data. Virtual Observatory (VO): purpose, definition of international standards, publication of catalogs and archives in the VO, VO-compliant tools, main bodies (International Virtual Observatory Alliance - IVOA, EURO-VO, Data Center Alliance - DCA).

Space Physics
Space missions: satellites and scientific instrumentation. Rockets, orbits, background, data transfer, Earth segment. Examples of observations and data analysis for the gamma-ray astrophysics. Geomagnetic field and its interaction with the cosmic environment. Radiation belts. Acceleration of particles in the magnetosphere. Particle acceleration processes in astrophysical sources. Magnetic reconnection and solar flares. Magneto-hydrodynamics shocks. First and second order Fermi acceleration processes. Non diffusive acceleration, wave and particle resonant scattering. Accelerations in the pulsars, relativistic winds. Accretion disks and acceleration models. Relativistic jets. High energy astrophysical sources, and analysis of the fundamental processes determining their X-ray, gamma, TeV emission at the light of most recent data.

Radiative Processes in Astrophysics 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.

Astrophysics Laboratory

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). Laboratory practice: sensors: calibration of a CCD (linearity and Photon Transfer technique).

High Energy Astrophysics

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.

Gravitational Waves

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.

Planetology

Origin of the Solar System. Classification of planets: general properties, moons, ring systems. Dynamic structure of the Solar System. Planetary interiors. Planetary surfaces, athmospheres and magnetospheres. Solar heating and transport energy. Minor bodies: trans-neptunian objects, comets, asteroids, meteors and meteor swarms. Planetary space missions. Extra-solar planets and planetary systems.