Indian Institute of Technology Kanpur

COURSES OF STUDY

2026





Indian Institute of Technology Kanpur
KANPUR-208016

DEPARTMENT OF S.P.A.S.E

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Course ID	**Course Title**	**Credits L-T-P-A-[C]**	**Content**
SPA201	Introduction to Astronomy and Astrophysics	3-0-0-0-9	This course will provide a foundation to UG students in the area of astronomy & astrophysics. Topics include a historical introduction, astrometry, universal physical principles and basics of radiation, observing tools, solar system and exoplanets, stellar structure and evolution, milky way and other galaxies, and basic introduction to cosmology.
SPA401	Galaxies and Observational Cosmology	3-0-0-0-9	Galaxy dynamics and evolution, tidal forces, stellar dynamics, virial theorem, interstellar medium; galaxy clusters, feedback mechanisms in clusters, intergalactic medium, Hubble's law and history of the Universe, cosmological parameters and parameter estimation.
SPA601	Space and Astronomical Instrumentation	3-0-0-0-9	Basic principles of space and astronomical instrumentation and detectors, electromagnetic wave and charged particle detectors, spectroscopy, spectroscopic techniques to deduce composition and physical properties, detector design, calibration, background, space qualification and data acquisition, detailed discussion of a few selected observatories, such as, AstroSat, Moon and Mars missions.
SPA602	Mathematical Methods in Space Sciences & Engineering	3-0-0-0-9	Vector analysis, vector di↵erential calculus, linear vector spaces, matrices, tensors, coordinate systems, Astronomical coordinate system transformation, ordinary diferential equations, stellar structure equations, special functions, Bessel function, Legendre function, spherical harmonics, application to cosmic microwave background radiation, Laplace trans-form, Fourier transform, Numerical Methods.
SPA603	Solar System Processes and Space Missions	3-0-0-9	Introduction ,Dynamics, Physics & Astrophysics: Two- and three- body problems; Thermodynamics; Stellar properties; Nucleosynthesis,Solar heating and energy transport: Energy balance and transport - conduction, convection, radiation ,Planetary atmospheres: Thermal structure; Composition; Molecular and eddy flows; Atmospheric escape,Planetary surfaces and interiors: Mineralogy & petrology; Interiors; Surface morphology, Impact cratering, examples.Magnetic fields: Sun; Solar wind; Planetary magnetospheres, Formation processes: Solar System - overview and constraints; Protoplanetary disk's evolution; Growth of solid bodies and gas giants; Migration; Planetary rotation; Asteroids, comets and moons; Exoplanets; Theory and observation,Major Space missions and their scientific contributions, Examples: Moon; Terrestrial planets; Gas giants .
SPA604	Numerical Methods in Space Sciences & Engineering	3-0-0-0-9	Numerical integration of functions, numerical root finding, numerical optimization of functions, integration of ordinary differential equations (ODE), Fast Fourier Transforms (FFT),

			Statistical parameter estimation, techniques for handling big data sets - potential and performance of parallel computing.
SPA610A	Fundamentals of Astronomy and Astrophysics	3-0-0-0-9	Historical introduction to astronomy, Multi-wavelength Observations, Astrometry, Coordinate systems, Photometry, Radiation from astronomical sources, Radiative transfer, Stellar spectra, Saha equation, HR diagram, Stellar Structure, Stellar nuclear reactions, Star formation and stellar evolution, Compact stars, Supernova explosions, Binary star systems, Milky Way galaxy, Introduction to galaxies, Large scale structure of the Universe.
SPA611A	Radio Astronomy	3-0-0-0-9	Fundamental of radio observations, radio antennas and receivers, antenna arrays, Response of an interferometer, cross-correlations, visibility function, calibration techniques, imaging, aperture synthesis, deconvolution, CLEAN algorithm, practical implementation on VLBI, VLA.
SPA612	Radio Astronomy Laboratory	0-0-9-0-9	Coax cable characterization, Filter characterization using oscilloscope and spectrum analyzer, 2-slit experiment in radio, designing and making a filter, Amplifier and mixer characterization, Design of Attenuator / Impedance Transformer, Observe HI line, Beam Pattern measurements, Antenna Design, Correlation, Power Divider / Combiner, Inter-ferometry to determine angular size of the Sun.
SPA615	Observational Techniques & Telescopes	3-0-0-0-9	This course will introduce students' observational techniques and telescopes in all major wavebands along with detectors and calibration aspects in astronomy. The Course will cover historically important instruments, optical and infra-red, radio, X-ray, multi-messenger astronomy, major observational facilities such as SKA, TMT, and LIGO, and description of various other observatories and planning aspects for securing observing time on international telescopes. There will be a few hands-on sessions using actual data and telescopes.
SPA620	Solar System Mechanics	3-0-0-9	Introduction to the Solar System, the 2-body problem, the restricted 3-body problem (R3BP), Applications of R3BP, Rotational and tidal effects, Applications to shapes of solar system and celestial bodies, Spin-orbit coupling, Perturbation methods and effects: The disturbing function, secular perturbations, resonance and chaos, Planetary rings.
SPA621	Planetary surface processes	3-0-0-0-9	Introduction ,Shapes of planetary bodies: Effect of rotation and tides; Topography, Continuum mechanics: Stress and strain; Linear elasticity; Bending and buckling of plates; Plasticity, Heat transfer: Fourier's law of conduction; Sources; Periodic heating and cooling; Stefan problem; Thermal stresses; Applications , Plate tectonics: Introduction; External and internal sources; Flexures and folds; Fractures and faults; Applications, Volcanism: Melting; Magma; Mechanics of eruption; Lava flows and domes, Impact cratering: Morphology; Cratering mechanics; Ejecta; Scaling laws; Atmospheric effects; Applications to landscapes, dating and evolution, Regolith and resurfacing processes: Growth; Heating; Weathering; Texturing; Creeping; Landsliding, Wind, water and ice on planetary surfaces.

SPA625	Space data acquisition and analysis	1-0-2-0-9	The course aims to introduce students to actual space data from space instruments in orbit. It will introduce the basic principles and techniques like; good or bad data and data selection, data analysis, instrument background, generating light curves, Power Density Spectrum (PDS), Energy spectrum and fitting of data using various emission as well as absorption models. Student will use data of LAXPC instrument onboard Astrosat. Using this data, Students will drive physical properites of the black hole and Neutron star X-ray bianries like source energy spectrum state: soft or hard, spectrum timing properites, thermonuclear burst, Neutron star spin frequency, High magnetic field of Neutron star, flux variation and others.
SPA660A	High Energy Astrophysics of Binary star systems	3-0-0-0-9	Review of stellar evolution and Compact stars, brief overview of Gas dynamics, plasma Physics and shock waves, binary stars, mass transfer through Roche lobe overflow and stellar wind, formation and structure 2 of accretion disks, steady α-disks, emitted spectrum, different X-ray states in compact star binaries, outbursts in X-ray binaries, detection of X-rays and gamma rays, space X-ray detectors, observations and study of X-ray binaries.
SPA661	Stars and Stellar Evolution	3-0-0-0-9	Introduction to Stars and interstellar medium, Stellar spectra and classification, Hertzsprung-Russell diagram, Stellar structure equations, Rosseland mean opacity, radiative pressure, stellar nuclear reaction, formation of stars, evolution on the main sequence and beyond, the end stages of stellar evolution, formation of compact stars, white dwarfs, neutron stars, black holes, supernova explosions, Binary stars.
SPA613M	Introduction to Celestial Observational Techniques	3-0-0-0-5	**Objectives:** The course will introduce basic concepts of Positional astronomy, observational techniques, signal properties with a few examples of observations of celestial sources. **Contents** (preferably in the form of 5 to 10 broad titles): • Positional astronomy: Night sky, celestial sphere, ancient astronomy, motion of planets, moon and comets, constellation and nakshtras, sidereal time, calendars, precession, proper motion and parallax, eclipses and transits, Astrometry, distance ladder, application of Stellarium software (7 lectures) • Measurements: Observations, brightness, intensity, flux, luminosity, magnitude scale, Photometry, spectroscopy (Doppler shift, spectral resolution, FWHM, convolution), filters, Atmospheric transmission windows on Earth, atmospheric seeing and extinction, effect of ionosphere (6 lectures) • Signal properties: - Signal & noise, wave and shot noise, sampling, VCZ theorem, coherence, Hanbury brown - Twiss effect, bunching of pli0tons (4 lectures) • Celestial objects (observational): Multi-wavelength observations of - solar system objects, exo-planets, stars (color-magnitude, HR diagram), Galaxies, large-scale structures. (4 lectures)

			Short summary for including in the Courses of Study Booklet: This course includes Positional astronomy, introduction to night sky, motions of celestial objects, measurement techniques, signal properties of celestial sources and their observations. **Recommended Books:** Astrophysical Techniques: C. R. Kitchin- To Measure the Sky: An Introduction to Observational Astronomy: Frederick R Chromey.
SPA614M	Introduction to Celestial Mechanics	3-0-0-0-5	This course helps describe various astronomical observations, primarily within the Solar System, employing relatively simple mechanical models. An introduction to galactic dynamics will also be given. The distribution is given below in terms of 50 minute lectures. • Introduction to the Solar System, stars and galaxies — 1 lecture • The 1- and 2- body problems: Kepler's laws, Newton's law of gravitation, Equations of motion, Mean and eccentric anomalies, Barycentric orbits, Orbital elements, Applications, e.g. Hohmann transfer — 4 lectures • Introduction to galactic dynamics: Collisionless N-body system (Coulomb logarithm, relaxation time, dynamical crossing time), Examples of galactic potentials, Orbits of stars in axisymmetric and non-axisymmetric potentials, Lindblad resonances — 4 lectures • The restricted 3- body problems: Equations of motion in a rotating frame, Tisserand relation, Jacobi integral, Lagrangian equilibrium points, Zero velocity curves, Perturbed orbits, Tadpole and Horseshoe orbits, Effect of drag, Applications to small moons — 6 lectures • Rotational and tidal effects: Tidal bulge, Potential theory, Tidal and rotational deformation, Shapes of solar system bodies, Roche zone, Tidal torques, Application to small moons — 6 lectures **Textbooks and references:** • Bertotti, B. , P. Farinella and D. Vokrouhlicky 2003. Physics of the Solar System: Dynamics and Evolution, Space Physics, and Spacetime Structure. Springer. • Binney, J. , and S. Tremaine 2008. Galactic Dynamics, 2nd ed. Princeton U. Press. • Danby, J. M. A. 1964. Fundamental of Celestial Mechanics. New York: Macmillan. • Diacu, F. , and P. Holmes 1996. Celestial Encounters. Princeton U. Press. • Fitzpatrick, R. 2012. An Introduction to Celestial Mechanics. Cambridge U. Press • Gurzadyan, G. A. 1996. Space Dynamics. London: Taylor Francis. • Murray, C. D. , and S. F. Dermott 1999. Solar System Dynamics. Cambridge Univ. Press. • Roy, A. E. 2005. Orbital Motion, 4th ed. CRC Press.
SPA617M	Space Instrumentation Laboratory	0-0-9-0-5	**Objectives**: The course aims to provide hands-on experience on instrumentation techniques related to astronomy, planetary and space sciences and engineering.

			Contents (preferably in the form of 5 to 10 broad titles): Students will be required to complete at least 2 experiments from each stream as described here – • Detector characterization in X-ray/UV/optical/nearIR; experiments related to working of CCD, CMOS, PMT, X-ray detectors etc. • Observing fundamental principles - Coherence, Van-CittertZernike theorem, Hanbury Brown intensity interferometer; Double slit experiment, Heisenberg uncertainty; Michelson/Fabry-Perot interferometer; Faraday effect; Young's modulus for different materials. • Spectroscopy and polarimetry techniques - Characterization of filters, polarizing elements and dispersing elements; Brewster angle, wave-plates-Spectrometer and polarimetry; spectral reflectance from surfaces, rocks and minerals in different. illumination conditions; Spectra of various gases and flamesA' - emission/absorption experiment; fibre optics; optical telescopes. • Radio detection techniques - Amplifiers, mixers, filters, noise & detection, phasing, antennas, RFI mitigation, impedance matching, transmission lines. Short summary for including in the Courses of Study Booklet: Experiments modules will consist of experiments related to electromagnetic wave detection and analyses in X-ray/UV/optical/IR/radio bands, observing fundamental principals (interference, diffracti011, coherence etc.), setting up spectroscopy and polarimetry experiments and carrying out related measurements applicable in field of astronomy, planetary and geological sciences. **Recommended Books:** Necessary reading material and instruction documents will be provided in the lab.
SPA618M	Introduction to radiative processes in space	3-0-0-0-5	Studying the universe is mostly done via understanding the electromagnetic radiation that each source emits. The nature of the spectrum indicates the underlying physical processes. This course intends to teach the processes that generate electromagnetic radiation and relevance in natural sources. **Content**: • Ionization processes (3 L): Basic quantum mechanics concepts (energy levels, wave-particle duality), Collisional ionization, photo-ionization, recombination, ionization equilibrium, HII regions (Stromgren sphere), Saha ionization • Emission and absorption of thermal plasma (5 L): Bound-Bound transitions, Spontaneous/ stimulated transitions, Einstein's coefficient, emission/absorption lines, emissivity and absorption coefficient, doppler/Lorentz broadening, Free-Free emission, Thompson scattering, example of a spectrum and its features • Heating and Cooling (2L): Physical conditions in different astrophysical systems (interstellar, intergalactic mediums),

			Photo-heating, cooling curve, thermal equilibrium, thermal instability, multiphase gas (interstellar medium) • Radiative Transfer (6 L): Radiative transfer equation, thermal radiation (Kirchhoff's law, blackbody radiation, Rayleigh-Jeans law), brightness temperature, Scattering and diffusion, radiation as a fluid (Eddington approximation), gray atmosphere, green house effect • Non-Thermal Radiation (4 L): Synchrotron Radiation, beaming effect, polarization, Compton/ inverse-Compton Scattering Short summary for including in the course study booklet: Ionization states of a plasma, enussion and absorption processes, heating and cooling, radiative transfer. **Books and references:** • Physics ofthe Interstellar and Intergalactic Medium: Bruce Draine • Radiative Processes in Astrophysics: Rybicki & Lightman
SPA622M	Mathematical Techniques in Space Sciences & Engineering	3-0-0-0-5	**Objectives:** The course aims to introduce students to numerical techniques used in Space Science & Astronomy. **Contents** (preferably in the form of 5 to 10 broad titles): • Vector Analysis (3 lectures) Vector differential calculus, gradient, divergence and curl, surface and volume integrals • Matrix Algebra (6 lectures) Introduction to matrices, diagonalization, solution of linear equations using matrices. • Coordinate Systems (5 lectures) Curvilinear coordinates, coordinate transformation, applications to astronomy • Ordinary differential equations (6 lectures) First and second order ODEs and their solutions. Separation of variables method to solve PDEs and various types of boundary conditions - initial value problem vs boundary value problem etc. Short summary for including in the Courses of Study Booklet: vecor analysis, vector differential calculus, linear vector spaces, matrices, tensors, coordinate systems, Astronomical coordinate system transformation, ordinary differential equations, examples from Astronomy **Recommended Books:** • Mathematical Methods in Classical and Quantum Physics, T. Dass S. K. Sharma • Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber and F. E. Harris, Elsevier, seventh edition. • Advanced Engineering Mathematics, E. Kreyszig, John Wiley & Sons, tenth edition.
SPA623M	Numerical Techniques in Space Sciences & Engineering	2-0-1-0-5	Space, Planetary and Astronomical Sciences and Engineering. **Contents** (preferably in the form of 5 to 10 broad titles): • Numerical Integration (2 lectures, 2 labs)

			Newton-Cotes formulae including trapezoidal rule and Simpson's rule, Gaussian quadrature, convergence and scaling of error, Monte Carlo Integration • Numerical Root finding (1 lecture, 1 lab) Bisection method, Newton Raphson method for single and multidimensional systems. • Integration of Ordinary Differential Equations (ODE) (3 lectures, 3 labs) Initial Value Problem Forward and backward Euler method, RungeKutta Method, Stiff system of equations, implicit vs. explicit schemes, shooting method for the Boundary Value Problem. • Numerical Interpolation of functions (1 lecture, 1 lab) Linear and higher order interpolation with polynomials, Spline Interpolation Short summary for including in the Courses of Study Booklet: Numerical integration of functions, numerical root finding, Solving Ordinary differential Equations, Numerical Interpolation **Recommended Books:** • Numerical Recipes: The Art of Scientific Cornputing Authors: Vertterling, Flannery, Press and Teukolsky. • Fundamentals of Numerical Computation Authors: Driscoll and Braun
SPA626	Space Environments and Space Systems	3-0-0-0[9]	Objectives: This course aims to provide the students the exposure to understand different aspects of the space environment, including space weather, space climate, space debris and how these impact on spacecraft design, terrestrial infrastructure systems and will enable students to explore particular topics at a deeper level
SPA627M	Introduction to fluid mechanics in space	3-0-0-0[5]	**Objective:** Fluid mechanics is used to describe the flows in a range of systems, starting from plane- tary atmosphere and the interior of stars to the flow of matter in the largest scale of the universe. This course intends to teach basics of the fluid mechanics and its applications to different astrophysical/geo-physical systems.
SPA628M	Introduction to Planetary Remote Sensing from Space Missions	2-0-3-0[5]	**Planetary surface properties and Radiation Interactions [5 lectures]** The character of planetary surfaces, differentiated and undifferentiated planetary bodies, solar system processes and interactions. Planetary regolith, megaregolith **Optical Image interpretation of planetary surfaces [3 lectures]** Elements of image interpretation, concept of spatial resolution, viewing geometry, Application in identifying active surface processes (viz. wind, water, ice) **UV-Vis-NIR Multi-Spectral and Hyperspectral Remote Sensing of planetary surfaces [5 lectures]**

			Spectrometer basics, Concept of Radiance, Reflectance, spectral resolution, basic spectral classification techniques (spectral parameters), and representation of spectral data (RGB composites), Application in mineral and elemental mapping **Topographic Data Analysis [4 lectures]** Laser ranging basics, Image-based Topographic analysis, Topographic data and products (topographic profile, digital elevation model), 2D interpolation techniques **Radar Remote Sensing [3 lectures]** Radar remote sensing basics, Dielectric properties of materials, Monostatic and Bistatic modes, Circular polarization ratio (CPR), Application to compositional and textural mapping **Pre-requisites, if any**: *Course on introductory geology, remote sensing or with the permission of the instructor* **Short summary for including in the Courses of Study Booklet**: This course would provide an overview of various types of remote sensing of planetary bodies carried out by space missions through time using various techniques. The student will be introduced to the analysis of remote sensing datasets from missions.
SPA629M	Introduction to Planetary Remote Sensing from Space Missions	2-0-3-0[5]	**1. Planetary surface properties and Radiation Interactions [5 lectures]** The character of planetary surfaces, differentiated and undifferentiated planetary bodies, solar system processes and interactions. Planetary regolith, megaregolith **2. Optical Image interpretation of planetary surfaces [3 lectures]** Elements of image interpretation, concept of spatial resolution, viewing geometry, Application in identifying active surface processes (viz. wind, water, ice **3. UV-Vis-NIR Multi-Spectral and Hyperspectral Remote Sensing of planetary surfaces [5 lectures]** *Spectrometer basics, Concept of Radiance, Reflectance, spectral resolution, basic spectral classification techniques (spectral parameters), and representation of spectral data (RGB composites), Application in mineral and elemental mapping* **4. Topographic Data Analysis [4 lectures]** Laser ranging basics, Image-based Topographic analysis, Topographic data and products (topographic profile, digital elevation model), 2D interpolation techniques **5. Radar Remote Sensing [3 lectures]** *Radar remote sensing basics, Dielectric properties of materials, Monostatic and Bistatic modes, Circular polarization ratio (CPR), Application to compositional and textural mapping.* **Pre-requisites, if any**: *Course on introductory geology, remote sensing or with the permission of the instructor* **(A) Short summary for including in the Courses of Study Booklet**: *This course would provide an overview of various types of remote sensing of planetary bodies carried out by space*

			missions through time using various techniques. The student will be introduced to the analysis of remote sensing datasets from missions.
SPA639	Satellite Based Communication & Navigation Techniques	3-0-0-0 (9)	The aim of this course is to introduce the students from the departments of SPASE, AE and EE to the fundamentals of the science and engineering topics related to satellite-based communication & navigation. The students will learn about the various parts of an artificial satellite, suitable orbits, communication links, modulation, coding and multiple access techniques and various applications. In the navigation part the course will cover the basic principles of navigation, example of existing global and regional systems, the three segments of GNSS, viz., Space segment, Control segment and Ground segment, navigation signal structures, measurements, sources of error and applications. The course is targeted for all engineering and science disciplines.
IDC614	Introduction to Space Weather	3-0-0-0 (9)	The objective of this course is to provide an introductory understanding of space weather by connecting the fundamental physics of the Sun to its far-reaching effects on the heliosphere and near-Earth environment. The course seeks to introduce the principles and challenges of space weather, enabling students to model, interpret, and anticipate various aspects of solarterrestrial interactions.
SPA641	Spacecraft Attitudinal Dynamics & Control	3-0-0-0 (9)	This course discusses the attitudinal dynamics and stability of a spacecraft. The lecture distribution is given below in terms of 42 lectures of 50 minutes each. 1. Rotational kinematics: Reference frames; Rotations; Angular displacement parameters; Angular velocity; Alternative parameters – 3 lectures 2. Attitude motion equations: Rigid body equations; Examples – 3 lectures 3. Attitude dynamics of a rigid body: Motion equations; Torque free motion of axisymmetric and general rigid body; Stability; Effect of torque; Examples of spacecraft torques; Effect of internal dissipation – 12 lectures 4. Multispin vehicles: Directional stability; Internal dissipation — 3 lectures 5. Spacecraft in orbit: Gravitational stabilization; Spin stabilization; Dual-spin stabilization — 9 lectures 6. Attitude hardware and modeling: Sun sensors; Horizon sensors; Magnetometers; Star sensors; Gyroscopes; Momentum & reaction wheels; Magnetic coils; Gas jets — 6 lectures 7. Attitude control: Feedback control; Momentum & reaction wheels; Nutation & libration damping; Gyroscope; Thrust vectoring — 3 lectures

			8. Attitude maneuver control: Spin-axis & spin-plane magnetic coil; Gas jet; Inertial guidance; Attitude acquisition — 3 lectures
SPA632M	Introduction to Mathematical Transforms and Applications in Space Sciences	3-0-0-0-(5)	(A) Objectives: This course aims to teach basic and most used mathematical transforms in various astronomical fields. (B) Contents (preferably in the form of 5 to 10 broad titles): 1. **Introduction to Linear Transformation** (2 lectures) Importance of transformations, uniqueness and reversibility, brief revision of operations like rotation, translation, reflection etc.., Riemann integrability etc.. 2. **Fourier Transforms & Applications** (8 lectures) Basics and properties of Fourier transforms, Fast Fourier Transform & inverse FFT, Parseval's theorem, convolution, correlation, windowing, resolution vs sampling, interpolation, solving boundary value problems, diverse applications of FFTs in astronomy, signal and image processing, spatial power spectrum, effects of quantisation, concept of matched-filtering (conjugate-filtering) 3. **Wavelet Transform and Applications** (4 lectures) Motivation for wavelets, Concept of scales, Mother wavelet and utilities to different types of signals (e.g. Haar), Wavelet spectrum, and feature identification 4. **Laplace Transform** (2 lectures) Definition and it's properties and connections with other transforms, inverse laplace transform, Hilbert transform, applications 5. **Radon & Hough Transforms** (3 lectures) Theory and applications (e.g. pulsars / solar) (C) Pre-requisites, if any: N/A (D) Short summary for including in the Courses of Study Booklet:
SPA631M	Statistical Methods and Applications	3-0-0-0-(5)	(A) Objectives: The course aims to introduce students to basics of statistical techniques, and some application used in astronomy and space physics. Initial course time is devoted to understanding and revision of basics followed by most used statistical techniques and data science. This course will be directed towards building a base for more advanced astronomy oriented data science applications. (B) Contents: 1. **Introduction to Multivariate Calculus** (1 lecture) Partial derivative, Gradients, Linearization of functions, Taylor Series approximation

			2. **Probability & Distribution** (3 lectures) Discrete Probability, Probability distribution & properties, Central limit theorem, K-S test, Bayes Theorem and inference with application to single variable model 3. **Uncertainty & Error Propagation** (6 lectures) random variables, standard error, variance, moments, noise: random & systematic, accuracy and precision, correlations & applications, Fisher Matrix & Covariance Matrix 4. **Numerical methods for Parameter Estimation Techniques** (6 lectures) minima and maxima, critical points, convexity, χ 2 estimation, constrained optimization, linear regression, Maximum likelihood estimators & examples, Priors & Posteriors 5. **Examples of Application to Astronomy Data** (2 lectures) Different astronomical datasets will be complied for this exercise 6. **Modern trends** (3 lectures) Monte-Carlo-Markov Chain simulations, K-means, Gaussian Mixtures etc.. (C) Pre-requisites, if any: N/A (D) Short summary for including in the Courses of Study Booklet: Statistical Methods / TechniquesProbability, distributions, error propagation, numerical optimization, regression, priors and posteriors, expectation-maximisation, applications to data science Commonality between topics will be taught.
SPA634	Optical Instrumentation Astronomy	3-0-0-0-(9)	Objectives: The course aims to introduce basic optics and then go into advance topics of optical design for astronomical telescopes and various instruments such as imagers, spectrographs. The course will also introduces high-angular resolution techniques such as adaptive optics and interferometry
SPA633M	Key concepts in Astrobiology and space biology	3-0-0-0-(5)	This course provides an in-depth understanding of astrobiology and space biology with a focus on future ISRO missions, including Chandrayaan-4, Chandrayaan-5, the Bharatiya Antariksha station, planned Venus and Mars missions. Students will explore key principles of life sciences in space, focusing on biosignature detection and microbial survival in extreme environments. The course will examine the biological challenges of human spaceflight, planetary protection protocols, and contributions to global astrobiology research by NASA, ESA, and ISRO, preparing students to contribute to upcoming space missions and advance life sciences research in space exploration contexts.
SPA624M	Optical Instrumentation Laboratory	3-0-0-0-(5)	Objectives: The course aims to provide comprehensive knowledge on instrumentation techniques related to astronomy, planetary and space

			sciences and engineering via building some application modules in the laboratory.
SPA636M	Radio instrumentation observing techniques and data analyses	3-0-0-0-(5)	This course aims to provide comprehensive knowledge on instrumentation, observing techniques, and data analyses related to radio astronomy via tutorials and lab experiments. This course will be in the basket of compulsory courses for the PhD students and MTech students.
SPA635M	Study of compact objects using real space data	3-0-0-0-(5)	Compact binraies (blackhole and neutron star X-ray binaries) use most efficient energy producing mechanism namely accretion. It produces very high temperature in the inner accreton disk and emits in X-ray. LAXPC instrument onboard Astrosat provides X-ray data best suted to study accretion flow in X-ray binaries. Student will use data of LAXPC instrument. It will introduce the basic principles and techniques like; good or bad data and data selection, data analysis, instrument background, generating light curves, Power Density Spectrum (PDS), Energy spectrum. Using this data, Students will drive basic physical properites of the black hole and Neutron star X-ray bianries like temperature, inner disk radii, source energy spectrum state: soft or hard, spectrum timing properites, thermonuclear burst, Neutron star spin frequency , flux variation and others.
SPA403M	Observing the Milky Way (galaxy) - Our home in the cosmos	3-0-0-0 [5]	The Milky Way galaxy is our home in the cosmos and its observations are fascinating for both amateurs and professional astronomers. This modular course covers a comprehensive observational perspective of the Milky Way. The course introduces Milky Way's composition, physical properties, size and location in the cosmos, its formation & evolution. The course aims to teach how each constituent is scientifically studied by astronomers and how are these studies important for astrophysicists
SPA638M	The Dynamics of Milky Way and Local Group of Galaxies	3-0-0-0-5	**a. Objectives:** Galaxies are fundamental building blocks of the large scale structure in our Universe. This course deals with fundamental principles governing the dynamics of disk (i.e. Milky Way/Andromeda), elliptical (i.e Sagittarius, M87) and dwarf galaxies (i.e. LMC/SMC) etc. Further, the course aims to provide familiarity with observations and numerical simulations techniques used in the galactic dynamics. **b. Contents:** (preferably in the form of 5 to 10 broad titles): **i. Introduction and Fundamentals [1 lectures]**: Overview of galaxies: morphology, kinematics and basic properties; Milky Way and local group of galaxies. **ii. Potential theory [3 lectures]:** Spherical density distribution, potential-density pairs of flattened system, potential of our Galaxy (Milky Way) **iii. Orbits of stars [2 lectures]:** Orbits in a given galactic potential (spherical/elliptical,

			axisymmetric/non-axisymmetric etc.), numerical orbit integration methods **iv. Equilibria of Collisionless Systems [4 lectures]:** Boltzmann equation, Jeans theorem, distribution functions, Jeans and Virial equations: assymetric drift, Virial theorem and related observations **v. Disk Dynamics and non-axisymmetric instabilities [5 lectures]:** Linear response theory, global stability of differentially rotating disk, fundamentals of spiral structures, bars, bending waves, warping and buckling of disk **vi. Collisions and encounter of stellar systems [2 lecture]:** Dynamical friction, mergers **vii Contemporary open problems in galactic dynamics [4 lecture]:** Perpespective of observations and simulations (idealized and cosmological simulations)
SPA404	Introduction to Space Technology	3-0-0-0 [91]	The objective of this course is to introduce the students from interdisciplinary Engineering streams to various topics of Space Technology which are imperative for the design, development, operation, and application of a spacecraft system.
SPA405M	Space Economics, Law, Policy, and Benefits	3-0-0-0 [5]	By the end of this course, students will: • Understand the fundamentals of the global and Indian space economy, emerging markets, and commercialization models. • Analyze the legal and regulatory frameworks that govern space activities—both internationally and nationally. • Explore space policy as a strategic and developmental tool—national security, scientific research, disaster management, and digital infrastructure. • Evaluate socio-economic and environmental benefits of space programs, especially in emerging economies like India. • Apply interdisciplinary thinking to emerging space challenges such as space traffic management, debris mitigation, PPPs in satellite constellations, and lunar economy.
SPA642M	Introduction to Adaptive Optics and Applications	3-0-0-0 (5)	Course Description (A) **Objectives:** To introduce the fundamental components and operation of adaptive optics systems, including wavefront sensing, reconstruction, and correction techniques for real-world applications. (B) Contents (preferably in the form of 5 to 10 broad titles):

			1. **Introduction**: Why adaptive optics? Imaging limitations of optical systems. Atmospheric turbulence and image degradation. Historical development of AO. Applications: Astronomy, Solar telescopes, Retinal imaging, Laser communications Defense and remote sensing. (2-lectures) 2. **Atmospheric Turbulence**: Refractive index fluctuations, Kolmogorov turbulence theory, Structure function, Fried parameter r0, Greenwood frequency, Isoplanatic angle, Coherence time, Seeing measurements, Turbulence profiling. (4 Lectures) 3**. Wavefront Sensing, Reconstruction and Correction Devices:** Principle of wavefront sensing, Shack–Hartmann wavefront sensor, Centroiding algorithms, Curvature sensing, Pyramid wavefront sensor, Sensor noise sources, Sensitivity and dynamic range. Influence functions, Interaction matrix, Reconstruction matrix, Least-squares reconstruction, Modal versus zonal reconstruction, Singular Value Decomposition (SVD). Deformable mirrors, MEMS deformable mirrors, Tip-tilt mirrors, Spatial Light Modulators, Actuator geometry, Stroke and fitting error. (8 Lectures) 4. **Closed-Loop Adaptive Optics Systems:** AO control loop architecture, Error budget, Servo lag error, Bandwidth considerations, Real-time control systems, Performance metrics. (4 Lectures) 5. **Advanced AO Concepts:** Laser Guide Stars, Natural Guide Stars, Multi-Conjugate AO (MCAO), Ground-Layer AO (GLAO) Extreme AO (ExAO), Multi-Object AO (MOAO). (3 Lectures)