Minor Degree Program in Astronomy

Centre of Excellence in Astronomical Studies
IEM Newtown
UEM Kolkata
2025

Image Courtesy: UEMK Observatory

Minor Degree Program

in

Astronomy

Centre of Excellence in Astronomical Studies

IEM Newtown

UEM Kolkata

Kolkata 700160

2025

Concept of Minor Degree:

With a view to enhance the employability skills and impart deep knowledge in emerging areas which are usually not being covered in Undergraduate Degree credit framework, IEM Newtown, UEM Kolkata has come up with the concept of 'Minor Degree' in emerging areas.

A. Definition of Credit:

1 Hr. Lecture (L) per week	1 Credit
2 Hours Practical (P) per week	1 Credit

B. Credits: 18 credits need to be covered by a student to be eligible to get a Minor Degree in: **Astronomy (ASTR)**.

C. Total Courses = 06 (Theory) + 02 (Practical) + 01 (Project) = 09
D. Total Credits = 18 (Sem III – Sem VII) + 2 (Optional, Sem VIII)
E. Name of the course: Astronomy (ASTR)

The following courses are included:

Semester	Subject Code	Subject Type	Course Name	Hours /Week	Credit(s)
III	MINOR301T	T	Introduction to Basic Astronomy – I	2 L	2
	MINOR391T	P	Familiarization with Telescope and accessories	2 P	1
IV	MINOR401T	T	Introduction to Basic Astronomy – II	2 L	2
	MINOR491T	P	Computational Astronomy with Numerical Analysis	2 P	1
V	MINOR501T	T	Introduction to Observational Astronomy	2 L	2
	MINOR591T	Project	Project	2 p	1
VI	MINOR601T	T	Astronomical Data Analysis & Astrostatistics	3 L	3
	MINOR691T	Project	Project (Continuation)	4 P	2
VII	MINOR701T	T	Elective (Any One): i) Archeoastronomy and Ancient Indian Chronology ii) Astrobiology iii) Stellar and galactic Astronomy	2 L	2
	MINOR791T	Project	Project (Final Submission)	4 P	2
				Total Credits	**18**
VIII	MINOR801T	T	Optional Topic: Introduction to Solar System Dynamics and Basic Celestial Mechanics	2 L	2
				Total Credits	**20**

Semester - III

MINOR301T MINOR391T	Introduction to Basic Astronomy – I Familiarization with Telescope and accessories	2L, 2P (per week) Total: 24 L 24 P	Total = 3 Credits

Introduction to Basic Astronomy – I

(Subject Code: MINOR301T)

Total Credit(s): 2

Total Lectures: 24

Prerequisites Engineering Physics, Engineering Mathematics

Course Objectives Familiarize students with:

1. Introduce the historical development of astronomy and its significance in different cultures.
2. Explore fundamental physical principles governing astrophysical phenomena.
3. Study the structure and dynamics of the solar system.
4. Introduce the basic concepts and significance of positional astronomy.
5. Explain the motions of celestial bodies within the solar system.
6. Understand astronomical timekeeping and celestial event cycles.

Course Contents

Module :1

Unit I: Introduction and Basic Concepts (2 lectures)

An overview; branches of astronomy, Importance; Introduction and basic concepts; The cosmos; its scale and character; Findings of JWST; The Sky.

Unit II: Astronomical Units (2 lectures)

Time units and definitions; distance units.

Unit III: Sun and Solar System (4 lectures)

The sun, its birth and lifecycle; The planets: inner planets and outer planets; Kuiper belt and Oort cloud; comets; Asteroid belt; Titius-Bode law; Natural satellites.

Unit IV: Stars (4 lectures)

Types and properties; Hertzsprung–Russell Diagram; Life cycle of stars; White dwarfs, Red giants, Neutron stars – Pulsars; Variable stars; Cepheid variables, their importance.

Module :2

Unit I: Introduction and Fundamental Concepts (2 lectures)

What is positional astronomy and its importance; The sky view as a celestial sphere; Fixed stars and wandering objects – the planets.

Unit II: The Solar System (8 lectures)

Its position and orientation in the Milky Way galaxy; Motion of the Earth and planets around the sun and the ecliptic plane; Motion of the moon; full moon and new moon; Motion of the planets; retrograde motion; Actual and apparent motions of the Earth and the heavenly bodies; Opposition and conjunction; Celestial equator and celestial ecliptic, celestial poles, meridian lines; Cardinal days; solstice and equinoctial days.

Unit III: Apparent Motions of the Sun and the Moon as Observed from the Earth (2 lectures)

Civil day and sidereal day; Synodic lunar month and sidereal lunar month.

Unit IV: Introductory Spherical Trigonometry (2 lectures)

Why spherical trigonometry? Spherical triangle; The major relationships and formulae

Unit V: Celestial Coordinates (2 lectures)

Horizontal system; Equatorial system; Ecliptic system; Galactic coordinate; Coordinate transformation.

Course Outcomes

Students will be able to:

1. Understand fundamental concepts of astronomy, including celestial spheres, stars, and planetary motions.
2. Describe the solar system, including the sun, planets, moons, comets, and asteroid belts, along with their motions and dynamics.
3. Analyse the types, properties, and life cycles of stars using tools like the Hertzsprung–Russell diagram and understand celestial time measurements.
4. Describe the celestial sphere and identify key celestial objects and their motions.
5. Interpret planetary and lunar motions, including phenomena like retrograde motion.
6. Differentiate between civil/sidereal days and synodic/sidereal months.

Text Books

1. Astronomy: A Beginner's Guide to the Universe; Eric Chaisson, and Steve McMillan; Pearson Education; Seventh edition.
2. Fundamental Astronomy; Hannu Karttunen; Springer-Verlag Berlin and Heidelberg GmbH & Co. K; 6th ed. 2017 edition.
3. To Measure the Sky: An Introduction to Observational Astronomy; Frederick R. Chromey; Cambridge University Press; 2nd edition.
4. Foundation of Astronomy; Michael A. Seeds; Brooks/Cole; International ed edition.
5. History of Science in India – Astronomy; Amitabha Ghosh; Ramakrishna Mission Institute of Culture.
6. Positional astronomy; Derek MacNally, Muller.
7. Textbook on Spherical Astronomy; W. M. Smart; Cambridge University Press; 6th ed.

Familiarization with Telescope and accessories

(Subject Code: MINOR391T)

Total Credit(s): 1

Total Practical Classes: 24

Course Objectives Familiarize students with

1. Basic experiments related to lens and mirrors.
2. Set up and align a telescope for basic astronomical observations.
3. Process and enhance astronomical images using standard techniques.

Course Contents

Unit I: Basic Experiments lenses and mirrors. Determination of the focal length and hence the power of convex lens and concave lens. Focal length of a convex and a concave mirror . Determination of the refractive index of the material of the convex lens. **(8 practical classes)**

Unit II: Telescope Setup, Hands-on experiment with telescope. **(6 practical classes)**

Unit III: Image Processing. **(10 practical classes)**

Text Books

1. Astronomy: A Beginner's Guide to the Universe; Eric Chaisson, and Steve McMillan; Pearson Education; Seventh edition.
2. To Measure the Sky: An Introduction to Observational Astronomy; Frederick R. Chromey; Cambridge University Press; 2nd edition.
3. Astronomical Image and Data Analysis; J.-L. Starck, F. Murtagh, Springer.

Course Outcomes

Students will be able to:

1. Develop practical skills in observational astronomy through hands-on telescope experiments, Stellarium simulations, and image processing.

Semester - IV

MINOR401T MINOR491T	**Introduction to Basic Astronomy – II** **Computational Astronomy with Numerical Analysis**	**2L, 2P (per week) Total: 24 L 24 P**	**3 Credits**

Introduction to Basic Astronomy – II

(Subject Code: MINOR401T)

Total Credit(s): 2

Total Lectures: 24

Prerequisites Basic Astronomy and Astrophysics, Basic Positional Astronomy

Course Objectives Familiarize students to:

1. Introduce the processes of nucleosynthesis and stellar element formation.
2. Explore exotic cosmic objects, galaxy structures, and large-scale universe organization.
3. Understand cosmological models and methods for measuring the universe.
4. Develop practical skills in measuring celestial phenomena and identifying constellations.

Course Contents

Module: 1

Unit I: Nucleosynthesis (2 lectures)

Primordial Nucleosynthesis, Stellar Nucleosynthesis: Overview of element formation in stars.

Unit II: Exotic Heavenly Objects (2 lectures)

Quasars; Black holes

Unit III: Galaxies (2 lectures)

Galaxies – Their types and properties; Milky Way galaxy; Our island universe; its structure and rotation; Galactic clusters.

Unit IV: Measuring the Universe (2 lectures)

Distance scales and estimation

Unit V: Cosmology (2 lectures)

Cosmological redshift and Hubble law; Big Bang model of the universe; Tired-light based and non-expanding models; Age of the universe and controversies.

Module: 2

Unit I: Daily Motion of the Sun (2 lectures)

Sun's motion and its variation throughout the year; Declination of the sun; Sunrise and sunset positions during a year.

Unit II: Precession of Earth's Axis (2 lectures)

Precessional motion of the spinning earth; Effects of precession in positional astronomy; Application of precession and archaeoastronomy.

Unit III: Observational Techniques and Celestial Phenomena (6 lectures)

Parallax and Proper Motion of Stars; Determination of Distances; Simple Experiments to Determine Cardinal Directions and Latitude; Eclipses and Transits of Venus and Mercury: Their importance; Important Constellations – Zodiacal and Others.

Course Outcomes

Students will be able to:

1. Apply spherical trigonometry and coordinate transformations in celestial observations.
2. Analyze the Sun's motion and understand the implications of Earth's precession.
3. Perform basic astronomical observations and interpret key celestial events.
4. Know about the production of elements in the universe.

Text Books

1. Astronomy: A Beginner's Guide to the Universe; Eric Chaisson, and Steve McMillan; Pearson Education; Seventh edition.
2. To Measure the Sky: An Introduction to Observational Astronomy; Frederick R. Chromey; Cambridge University Press; 2nd edition.
3. Astronomical Image and Data Analysis; J.-L. Starck, F. Murtagh, Springer.
4. Positional astronomy; Derek MacNally, Muller.
5. Textbook on Spherical Astronomy; W. M. Smart; Cambridge University Press; 6th ed.

Computational Astronomy with Numerical Analysis

(Subject Code: MINOR491T)

Total Credit(s): 1

Total Practical Classes: 24

Prerequisites Basic Astronomy and Astrophysics, Basic Positional Astronomy

Course Objectives Familiarize students to:

1. Introduce fundamental numerical techniques for solving mathematical problems.
2. Develop skills in interpolation, root finding, and curve fitting.
3. Apply numerical methods to solve basic problems in celestial mechanics.

Course Contents

Unit I: Numerical Methods (24 practical classes)

Overview of numerical computation - Simple problems: data sorting, root finding, etc; Numerical solutions of algebraic equations; interpolation/extrapolation; Curve fitting, Celestial problem solving using numerical methods.

Course Outcomes

Students will be able to:

1. Implement numerical techniques for solving algebraic and transcendental equations.
2. Use interpolation and curve fitting for data analysis and modelling.
3. Solve astronomy-related problems using appropriate numerical methods.

Text Books

1. Numerical Methods in Astrophysics: An Introduction; P. Bodenheimer, G. P. Laughlin, M. Rozyczka, T. Plewa, & H. W. Yorke; CRC Press. (1st ed.).
2. Numerical Python in Astronomy and Astrophysics: A Practical Guide to Astrophysical Problem Solving; Wolfram Schmidt, Marcel Völschow Publisher; Springer.

Semester - V

MINOR501T MINOR591T	**Introduction to Observational Astronomy** **Project**	**2L, 2p (per week)** **Total: 24 L** **24 P**	**Total = 3 Credits**

Introduction to Observational Astronomy

(Subject Code: MINOR501T)

Total Credit(s): 2

Total Lectures: 24

Prerequisites Basic Astronomy and Astrophysics.

Course Objectives

Familiarize students with

1. Introduce the fundamentals and tools of observational astronomy across the electromagnetic spectrum.
2. Explore various ground-based and space-based telescope systems and their applications.
3. Familiarize students with modern observational techniques and emerging trends in astronomy.

Course Contents

Module: 1

Unit I: Introduction and Fundamentals (5 lectures)

Definition, importance and branches; Electromagnetic spectrum, types of radiation and astronomical applications; Spectroscopy and its relevance; Optical telescope; historical perspective, progress with time for both refracting and reflecting telescopes; Detectors and instrumentation; photomultiplier, CCDs and spectrographs; Observing techniques and strategies

Unit II: Optical Astronomy (5 lectures)

Optical telescopes and instruments; refracting, reflecting and catadioptric telescopes; Photometry and spectroscopy; measurement of optical brightness and analysing spectral energy distribution; Optical interferometry and imaging; high-resolution imaging and interferometric techniques; Optical observation of stars and galaxies; stellar photometry, spectroscopy; Optical observation of planets and minor bodies – planetary photometry, spectroscopy.

Unit III: Radio and Millimeter-wave Astronomy (5 lectures)

Radio telescope principle; Instruments and data processing; Single dish and interferometry-based multi-dish astronomy; Radio observation of stars and galaxies; stellar radio emission, galaxy radio surveys; Radio observation of planets and minor bodies; Millimeter-wave and submillimeter-wave astronomy; Infrared telescopes; infrared observation of stars and galaxies; Ultraviolet and X-ray telescopes and instruments; stellar UV/X-ray emission, galaxy UV/X-ray surveys; High energy astrophysics and gamma-ray astronomy – telescopes, instruments and observations.

Unit IV: Space Telescopes (3 lectures)

Hubble telescope; Chandra telescope; JWST telescope

Unit V: Specialized Observational Techniques (3 lectures)

Astrometry and interferometry; high-resolution imaging; Spectroscopy and spectroscopic analysis Gravitational lensing; Exoplanet detection and characterization.

Unit VI: Advanced Topics and Current Research (3 lectures)

Next-generation telescopes and instruments; future facilities, technologies; Space-based astronomy and missions; Computational methods and data analysis; Machine learning and AI in astronomy – applications and future directions; Frontiers in observational astronomy and emerging trends.

Course Outcomes

Students will be able to:

1. Explain the principles and instrumentation of optical, radio, and high-energy astronomy.
2. Apply observational techniques to study celestial bodies across multiple wavelengths.
3. Analyse current and future advancements in astronomical observation and data analysis.

Text Books

1. Observational Astronomy; D Scott Birney, Guillermo Gonzalez, David Oesper; Cambridge University Press.
2. To Measure the Sky: An Introduction to Observational Astronomy; Frederick R. Chromey; Cambridge University Press; 2nd edition.

Project

(Subject Code: MINOR591T)

Total Credit(s): 1

Total Classes: 24

Course Objectives

Familiarize students with

1. Provide practical research experience in analysing real astronomical data.
2. Encourage application of statistical, computational, and analytical tools in astronomy.
3. Foster independent problem-solving and scientific inquiry in observational and theoretical contexts.

Course Contents

Unit 1: Project Work in Astronomy

Objective: The project work aims to provide students with hands-on experience in astronomical research, allowing them to apply theoretical concepts learned in the course to real-world problems in astronomy.

Topics: Students can select topics related to the following areas (but not limited to):

- Astronomical Data Analysis (e.g., analysis of sky surveys, pulsar data, etc.)
- Regression models in astronomical research
- Time series analysis of astronomical phenomena (e.g., star variability, solar activity)
- Clustering and classification of astronomical objects (e.g., galaxy classification, star grouping)
- Spectral and image data processing
- Development and application of computational tools for astronomical research.

Course Outcomes

Students will be able to:

1. Conduct independent research using real-world astronomical datasets.
2. Apply statistical and computational methods to investigate astronomical phenomena.
3. Develop a research foundation that can be extended into future academic or professional projects.

Semester - VI

MINOR601T **MINOR691T**	**Astronomical Data Analysis & Astrostatistics Project**	**3L, 4P (per week)** **Total: 24 L** **24 P**	**Total =** **5Credits**

Astronomical Data Analysis & Astrostatistics

(Subject Code: MINOR601T)

Total Credit(s): 2

Total Lectures: 24

Prerequisites Engineering Physics, Engineering Mathematics, Numerical methods.

Course Objectives Familiarize students with

1. Understand and apply astronomical data sources and software tools for research.
2. Analyse and model complex data using advanced regression techniques and statistical methods.

3. Develop skills in time series analysis, dimension reduction, and clustering for astronomical data analysis.

Course Contents

Module: 1

Unit I: Astrostatistics (12 lectures)

Introduction, Variable, Discrete-Continuous, Qualitative–Quantitative, Cause and Effects, Frequency Distribution, Central Tendency, Dispersion, Skewness, Kurtosis.

Exploratory Data Analysis, Histogram, Box Plot, Correlation, Scatter Plot, Regression, Multiple Correlation, Random Variable, Some Important Discrete Distributions, Some Important Continuous Distributions.

Statistics, Numerical methods for Parameter Estimation Techniques -- minima and maxima, critical points, convexity, χ2estimation, constrained optimization, linear regression, Maximum likelihood estimators & examples

Module: 2

Unit 1: Sources of Astronomical Data (4 lectures)

Astronomical databases, Sky surveys, Catalogue services, Specialized star and galaxy data, Software tools

Unit 2: Advanced Regression and Applications (4 lectures)

Simple and multiple regression, Model selection methods, Regularization techniques, Astronomical regression analysis

Unit 3: Missing Data and Imputation (6 lectures)

Types of missing data, Basic imputation methods, EM algorithm, Multiple imputation

Unit 4: Dimension Reduction, Clustering, and Data Mining (6 lectures)

Principal Component Analysis (PCA), Independent Component Analysis (ICA), Factor Analysis, Clustering Techniques (Hierarchical, k-Means), Classification, Clustering in Large Data Sets, Subspace and Data Mining Methods

Unit 5: Time Series Analysis (6 lectures)

Time series components, Stationarity, Autocorrelation, Stochastic processes, Time series models (stationary & non-stationary), Parameter estimation, Forecasting, Spectral analysis, Cross-correlation

Course Outcomes

Students will be able to:

1. Students will be able to effectively use astronomical data sources for research and analysis.
2. Students will be proficient in applying advanced regression techniques and statistical models to complex data.
3. Students will gain expertise in time series analysis, dimension reduction, and clustering for astronomical data interpretation.

4. Apply statistical methods to analyze astronomical data.
5. Gain proficiency in numerical methods for parameter estimation and optimization.
6. Capable of performing exploratory data analysis and regression in astronomical contexts.

Text Books

1. Statistical Methods for Astronomical Data Analysis; Asis Kumar Chattopadhyay, Tanuka Chattopadhyay; Springer.
2. Astrostatistics; Gutti Jogesh Babu, E.D. Feigelson (Author);Chapman and Hall/CRC.
3. Statistics, Data Mining, and Machine Learning in Astronomy: A Practical Python Guide for the Analysis of Survey Data; Željko Ivezić, Andrew J. Connolly, Jacob T. VanderPlas, and Alexander Gray; Princeton University Press.

Project

(Subject Code: MINOR601T)

Total Credit(s): 2

Total Classes: 24

Course Objectives

Familiarize students with

4. Provide practical research experience in analysing real astronomical data.
5. Encourage application of statistical, computational, and analytical tools in astronomy.
6. Foster independent problem-solving and scientific inquiry in observational and theoretical contexts.

Course Contents

Unit 1: Project Work in Astronomy

Objective: The project work aims to provide students with hands-on experience in astronomical research, allowing them to apply theoretical concepts learned in the course to real-world problems in astronomy.

Topics: Students can select topics related to the following areas (but not limited to):

- Astronomical Data Analysis (e.g., analysis of sky surveys, pulsar data, etc.)
- Regression models in astronomical research
- Time series analysis of astronomical phenomena (e.g., star variability, solar activity)
- Clustering and classification of astronomical objects (e.g., galaxy classification, star grouping)
- Spectral and image data processing
- Development and application of computational tools for astronomical research.

Course Outcomes

Students will be able to:

1. Conduct independent research using real-world astronomical datasets.
2. Apply statistical and computational methods to investigate astronomical phenomena.
3. Develop a research foundation that can be extended into future academic or professional projects.

Semester - VII

MINOR701T MINOR791T	**Elective (Any One) :** • Archeoastronomy and Ancient Indian Chronology • Astrobiology • Stellar and galactic Astronomy Project	2L, 4P (per week) Total: 24 L 24 P	Total = 4 Credits

Archeoastronomy and Ancient Indian Chronology

(Subject Code: MINOR701T)

Total Credit(s): 2

Total Lectures: 24

Prerequisites Engineering Physics, Engineering Mathematics, Numerical methods.

Course Objectives

Familiarize students with

1. Introduce the role of astronomy in historical and chronological studies.
2. Explore archaeoastronomical methods and their relevance to ancient Indian texts.
3. Encourage interdisciplinary analysis using astronomical, archaeological, and textual evidence.

Course Contents

Unit I: Introduction (2 lectures)

Preamble; Importance of chronology in history; Problems with establishing ancient chronology of India; Application of astronomical technique and its importance.

Unit II: Basic Principles of Archaeoastronomy (6 lectures)

What is archaeoastronomy and its types; Physical archaeoastronomy; Descriptive archaeoastronomy Secular variation in astronomical parameters; major role played by the precessional motion of the earth's axis; Ancient eclipses and Saptarshi cycle; Various observational effects of precession; Evolution of planet Mars

Unit III: Astronomy in Ancient India (2 lectures)

Pre-siddhantic astronomy, and Vedanga Jyotish; Discovery of ancient Indian astronomical knowledge.

Unit IV: Astronomical References in Vedic and other ancient texts (6 lectures)

Heliacal risings; Madhu Vidya, Location of Orion's head, Dog of Yama and the Sun; Atri's Pitamaha yajna parigrah – Rohini legend; Solar eclipse at noon on the summer solstice day.

Unit V: Astronomical References in Brahmana and Mahabharata (4 lectures)

Risings of Kritika; Solar eclipse and funeral rites; Astronomical references in Mahabharata; Balarama's death; Exaltation of Mars.

Unit VI: Archaeological, Geological and Genealogical Indicators (4 lectures)

Correlation with astronomical dating; Lost river Saraswati; Changing sea level; Genealogical lists; Recent archaeological discoveries.

Course Outcomes

Students will be able to:

1. Interpret astronomical references from ancient Indian literature and cultural practices.
2. Analyze historical events using archaeoastronomical and geological indicators.
3. Build a foundation for extended research in archaeoastronomy and Indian chronology

Text Books

1. History of Science in India – Astronomy; Amitabha Ghosh; Ramakrishna Mission Institute of Culture**.**
2. Descriptive Archaeoastronomy and Ancient Indian Chronology; Amitabha Ghosh; Springer Verlag

Astrobiology

(Subject Code: MINOR701T)

Total Credit(s): 2

Total Lectures: 24

Prerequisites Engineering Physics, Engineering Mathematics, Numerical methods.

Course Objectives

Familiarize students

1. To explore the origin and evolution of life with a focus on organic molecule formation and early Earth conditions;
2. To understand microbial adaptations in extreme environments relevant to astrobiology and space exploration;
3. To familiarize students with life detection techniques, planetary protection protocols, and India's role in space-based astrobiology research;

Course Contents

Unit I: Origins of Life and Organic Molecules (4 lectures)

Origin of organic molecules on early Earth and in space; Role of hydrothermal vents in abiotic synthesis; RNA world hypothesis and self-replication mechanisms; Emergence of cellular life and early metabolic pathways; Evolution of oxygenic photosynthesis and its planetary impact.

Unit II: Life in Extreme Environments (4 lectures)

Microbial adaptations to radiation, pressure, gravity, and temperature; Survival in geochemical extremes: acidic, alkaline, saline, anoxic environments; Astrobiological relevance of extremophiles; Simulation of lunar and Martian surface and subsurface environments.

Unit III: Defining and Detecting Life (4 lectures)

Definitions and criteria for life (terrestrial and non-terrestrial); Strategies for searching for known and unknown life forms; Molecular and isotopic biosignatures; Analytical and technical challenges in life detection; Distinguishing between abiotic and biotic signals.

Unit IV: In-Situ Life Detection and Planetary Protection (4 lectures)

In-situ detection techniques and instrumentation; Contamination control protocols and sterilization procedures; Instrument validation in lab, suborbital flights, CubeSats, and ISS; Planetary protection policies and ethical considerations.

Unit VI: Astrobiology in Indian Space Missions (4 lectures)

Gaganyaan mission: human spaceflight and life science experiments; Chandrayaan-4 and Chandrayaan-5: potential for lunar astrobiology; Bharatiya Antariksha Station: future platform for space biology research; Indian missions to Venus and Mars: biosignature detection strategies and goals; Role of ISRO in advancing astrobiology research and international collaborations.

Course Outcomes

Students will be able to:

1. Students will be able to explain the biochemical and geophysical processes involved in the emergence of life.
2. Students will gain insight into survival strategies of extremophiles and their astrobiological significance.
3. Students will be equipped to evaluate life detection methods and assess the contributions of Indian space missions in astrobiology.

Text Books

1. Astrobiology: A Very Short Introduction; David C. Catling; Oxford.
2. Astrobiology: Understanding Life in the Universe; Charles S. Cockell; Blackwell Pub.

Stellar and Galactic Astronomy

(Subject Code: MINOR701T)

Total Credit(s): 2

Total Lectures: 24

Prerequisites Engineering Physics, Engineering Mathematics, Numerical methods.

Course Objectives

Familiarize students with

1. To explore the fundamental processes of stellar formation, evolution, and death.
2. To understand the structure, dynamics, and classification of galaxies.
3. To study advanced topics in high-energy astrophysics, black holes, and exoplanet detection methods.

Course Contents

Unit 1: Introduction to Stellar Astronomy and Formation (6 lectures)

Stellar Astronomy Overview, Stellar Classification, Spectra & Luminosity, Temperature & Brightness, Hertzsprung-Russell Diagram, Parallax & Distance Measurement, Nebulae & Star Formation, Stellar Life Cycle, Nuclear Fusion, Stellar Nucleosynthesis.

Unit 2: Stellar Death and Remnants (4 lectures)

White Dwarfs & Neutron Stars, Black Holes, Supernovae, Gravitational Waves in Stellar Collapse.

Unit 3: Galactic Astronomy (4 lectures)

Milky Way Structure, Galactic Coordinate System, Galactic Rotation, Dark Matter, Galactic Morphology, Hubble's Tuning Fork, Galactic Centre & Supermassive Black Hole, Active Galactic Nucleus (AGN).

Unit 4: Galaxy Formation, Evolution, and Extragalactic Astronomy (6 lectures)

Galaxy Formation Theories, Dark Matter, Hierarchical Model, Galaxy Interactions, Starbursts & Active Galaxies, Galaxy Clusters, Cepheid Variables, Redshift & Hubble's Law, AGN & Quasars, Expanding Universe, Big Bang Theory, Cosmic Microwave Background (CMB).

Unit 5: Current Topics in Stellar and Galactic Astronomy (4 lectures)

High-Energy Astrophysics, Gravitational Lensing & Black Hole Physics, Exoplanets & Stellar Systems.

Course Outcomes

Students will be able to:

1. Understand the processes of stellar formation, evolution, and death.
2. Analyse the structure and dynamics of galaxies and the universe.

3. Apply modern techniques in high-energy astrophysics and exoplanet detection.

Text Books

1. Astrophysics: Stars and Galaxies; K. D. Abhyankar; Universities Press.
2. Introduction to Astrophysics; Baidyanath Basu, Tanuka Chattopadhyay, Sudhindra Nath Biswas; PHI.
3. Galaxies in the Universe: An Introduction; Linda Siobhan Sparke, III Gallagher, John S.; Cambridge University Press.

Project

(Subject Code: MINOR791T)

Total Credit(s): 2

Total Classes: 24

Course Objectives

Familiarize students with

7. Provide practical research experience in analysing real astronomical data.
8. Encourage application of statistical, computational, and analytical tools in astronomy.
9. Foster independent problem-solving and scientific inquiry in observational and theoretical contexts.

Course Contents

Unit 1: Project Work in Astronomy

Objective: The project work aims to provide students with hands-on experience in astronomical research, allowing them to apply theoretical concepts learned in the course to real-world problems in astronomy.

Topics: Students can select topics related to the following areas (but not limited to):

- Astronomical Data Analysis (e.g., analysis of sky surveys, pulsar data, etc.)
- Regression models in astronomical research
- Time series analysis of astronomical phenomena (e.g., star variability, solar activity)
- Clustering and classification of astronomical objects (e.g., galaxy classification, star grouping)
- Spectral and image data processing
- Development and application of computational tools for astronomical research.

Course Outcomes

Students will be able to:

4. Conduct independent research using real-world astronomical datasets.
5. Apply statistical and computational methods to investigate astronomical phenomena.
6. Develop a research foundation that can be extended into future academic or professional projects.

Semester - VIII

MINOR801T	Introduction to Solar System Dynamics and Basic Celestial Mechanics	2L (per week) Total: 24 L 24 P	Total = 2 Credits

Introduction to Solar System Dynamics and Basic Astrodynamics / Celestial Mechanics

(Subject Code: MINOR801T)

Total Credit(s): 2

Total Lectures: 24

Course Objectives

Familiarize students with

1. To understand the fundamental laws governing planetary motion and gravitational interactions in space systems.
2. To explore analytical and numerical methods for solving two-body and restricted three-body problems.
3. To apply orbital mechanics concepts to real-world scenarios such as orbit transfers, perturbations, and mission planning.

Course Contents

Unit I: Foundations of Orbital Mechanics (4 lectures)

Kepler's Laws, Newton's Law of Gravitation, Titius–Bode Law, Historical Overview.

Unit II: Two-Body and Three-Body Problems (4 lectures)

Equations of Motion, Orbital Elements, Mean and Eccentric Anomalies, Barycentric Orbits, Restricted Three-Body Problem, Lagrangian Points, Jacobi Integral, Stability.

Unit III: Gravitational Fields and Potentials (4 lectures)

Gravitational Field and Potential, Legendre Polynomials, Spherical Harmonics, MacCullagh's Approximation, Fields of Non-Spherical Bodies.

Unit IV: Tidal Effects and Rotational Dynamics (4 lectures)

Tidal Bulge, Rotational Deformations, Spin-Orbit Coupling, Tidal Evolution, Resonances.

Unit V: Orbital Mechanics and Perturbation Methods (4 lectures)

Orbit Types (Bounded/Unbounded), Perturbation Theory, Encke's Method, Osculating Orbits, Variation of Parameters, Lagrange's Planetary Equations.

Unit VI: Advanced Orbit Dynamics and Transfer (4 lectures)

Orbit Transfer Techniques, Hohmann Transfer, Patched-Conic Approximation, Fly-by, Grand Tour Planning, Secular Changes, Sphere of Influence.

Course Outcomes

Students will be able to:

1. Apply the principles of celestial mechanics to analyse and predict orbital motion.
2. Solve two-body and restricted three-body problems using mathematical models and approximations.
3. Design and evaluate orbit transfers and mission trajectories using perturbation and planning techniques.

Text Books

1. Galactic Dynamics, James Binney and Scott Tremaine; Princeton University Press.
2. An Introduction to Celestial Mechanics; Forest Ray Moulton; Dover Publications.