Program Objectives and Outcomes

M.Sc. ASTRONOMY & M.Sc. ASTROPHYSICS

M.Sc., Astronomy and Astrophysics is a course which requires both scientific and analytical skills. All the fruits of scientific and technological developments that the world witnessing today are source back to be astronomical inventions. It is a growing science that will continue to produce discoveries in the coming days too. With that vision, M. Sc., Astronomy and Astrophysics course at PG level has been initiated and is still continuing.It is the only Department which offers the course at PG level in university.

SEMESTERI

Theory

1. AS 101: Basic Physics

Objectives:

To expose the students to the Electromagnetic Theory in the different regions ofthe Electromagnetic spectrum to technological applications and natural phenomena.Create and solve equations relating frequency, wavelength, speed and energy. Incanonical transformations we use to express a problem, preserving the form of Hamilton'sequations. From Statistical Mechanics we used to express application of MB, FE and BEdistribution functions. To have a comprehensive physical idea and mathematicalunderstanding of Special theory of Relativity and its applications in Electrodynamics.

Outcomes:

The student has gained -

Understand the basic mathametical concepts related to electromagnetic vector field. Apply Maxwell's equations to solutions of problems relating to transmission uniformplane wave propagation. Understand the concepts related to faraday's law, induced emf and Maxwell'sequations.Understand canonical ensemble and arrive at expression for partition function andits computation.The student is able to apply classical and quantum probability distribution functionsto various systems.Analytical and problems solving skill to apply principles of statistical physics tovarious system in thermal equilibrium.

2. AS 102: Mathematical Methods of Physics

Objectives:

Understand and solve second-order ordinary differential equations (ODEs), including both homogeneous and non-homogeneous types with constant and variable coefficients, using methods such as power series and Frobenius.Learn to solve partial differential equations (PDEs) using separation of variables,focusing on equations like the wave, Poisson's, Laplace's, and heat conduction equations.Study special functions such as Hermite polynomials, Gamma, Beta, Legendre, andBessel functions, and their applications in solving physical problems.Understand Fourier series, including its definition, expansion of functions, intervalextension, and the advantages and complex form of Fourier series.Explore Fourier transforms and their applications, including Fourier integrals, transformsof derivatives, Parseval's relation, and their use in solving definite integral.

Outcomes:

Students will solve second-order ODEs with various methods and apply theSuperposition Principle to find solutions for differential equations like Legendre's andBessel's.Students will use separation of variables to solve PDEs such as the wave, Poisson's,Laplace's, and heat conduction equations, and understand Euler's and Riccati equations.Students will apply special functions like Hermite polynomials and Bessel functions tosolve differential equations, and understand their properties and applications.Students will expand functions into Fourier series, understand the advantages of usingFourier series, and convert them into complex forms.Students will use Fourier transforms to solve problems involving integrals andderivatives, and apply Parseval's relation to various definite integrals.

3. AS 103: Basic Astronomy

Objectives:

Describe the primary constituents of the Universe on scales from the solar systemto observational frontiers, and place these constituents in context with theappropriate measures of space and time.Connect observations of the Universe with the fundamental laws and principlesthat govern the behaviour of the physical world.Learn the history of modern observational astronomy, with a key focus on how theinterpretation of results from experimentation and observation guided thedeployment of astronomy.Explore the objects that comprise the solar system, with focus on chemical andatmospheric composition and how these interact to determine the changing natureof planetary environments.

Outcomes:

The course helps to understand the observed properties of physical systems that comprise the known universe, on various scales and exploring nature of celestial objects.

4. AS 104: Classical (Celestial) Mechanics

Objectives:

Students will be familiar with Newtonian and Keplerian mechanics to solve the formulations oftwo-body, three-body, Restricted three-body and N-body problems. Students will learnLagrangian and Hamiltonian formulations of mechanics of a particle and system of particles.Students will also learn the fundamental equations of rocket dynamics and interplanetary transferorbits.

Outcomes:

Upon successful completion of the course, the student:

Unit-I: will learn formulation and the solution of the two-body problem based on the Newtonian mechanics. And also learn Kepler's equation and its solution.

Unit-II: will be familiar with equations of motion of three-body problem and its particular

solution by Lagrangian method, Restricted three-body problem and Lagrangian points.
Unit-III: will be familiar with the equations of motion in the N-body Problem, ten integrals of motion of the n-body problem, perturbing function and virial theorem.
Unit-IV: will be familiar with Lagrangian& Hamiltonian formulation of mechanics and equations of motion of two-body problems and three body problem in Lagrangian formulation. And also learn Cyclic or ignorable coordinates and Hamilton-Jacobi partial differential equation.
Unit-V: will learn about fundamental equations of motion of a rocket in a gravitational field and in an atmosphere, Step rockets and interplanetary transfer orbits.

Practicals

1. AS Pr 151: Numerical Methods and Computer Applications Python

Objectives:

To impart the knowledge of various techniques in numerical methods for finding the numerical solutions to the problems, including applications in Astronomy. Learn the concepts of python programming language for wide variety of technical applications, including the concepts learnt in the numerical methods for applications in Astronomy.

Outcomes:The students will be capable of –

Solving the given problems using numerical methods and execute the same through the python programming. Writing independently codes in python for computations as well as plotting the results.Drafting the report for the lab work performed in a suitable technical format.

2. AS Pr 152: Data Handling using GNU plot and Astronomical Distance Estimation Techniques

Objectives:

The aim of the paper is to introduce the GNUplot program to students and teach them to use this flexible, universal and free tool to produce various graphs from data. This capability can then be applied within other courses where they need to produce graphs and also later in applied research.Learn different astronomical distance estimation techniques and determine them for the given data.

Outcomes:The students will be capable of –

Use Gnuplot program to produce graphical representation of given data in the desired format. Create best fit theoretical plot and functions for the data used in the plot.Search for astronomical data for distance estimation from various databases and research work.Apply the concepts of distance estimation techniques, compute and determine the acceptable value of distance for the given astronomical objects.Draft the report on the work performed in systematic format to represent their work effectively.

SEMESTER II

Theory

1. AS 201: Quantum Mechanics

Objectives:

The course introduces Schrödinger equations with solutions in simple potentials, includingharmonic oscillator, spherically symmetric potentials with hydrogen-like atoms. Thequantum mechanics are introduced; matrix representation of quantum mechanics isdiscussed together with approximate methods (the variational method, perturbation theory,Born approximations). Program also covers spin and angular momentum representationsand addition rules and identical particles treatment.

Outcomes:

The student is able to:

Apply principles of quantum mechanics to calculate observables on known waveFunctions.Solve time-dependent and time-independent Schrödinger equation for simplePotentials.Apply the variational method, time-independent perturbation theory and time-dependent perturbation theory to solve simple problems.Combine spin and angular momenta.The student has gained knowledge about fundamental quantum mechanicalprocesses in nature.

2. AS 202: Fluid Mechanics and Magneto Hydro Dynamics

Objectives:

Understand the basics of fluid mechanics, including how fluids move, key concepts likevelocity potential and vorticity, and important equations such as Euler's and Bernoulli's.Grasp the principles of gas dynamics, focusing on wave motion, the speed of sound ingases, and the formation and effects of shock waves and Mach numbers.Study the motion of charged particles in electric and magnetic fields, including particledrifts, the mirror effect, and adiabatic invariants.Learn about the Compton and inverse Compton effects, analyze the y-parameter andCompton spectrum, and understand fluid instabilities like Kelvin-Helmholtz andRayleigh - Taylor.Comprehend magnetohydrodynamics, including Maxwell's equations in moving media,magnetic diffusion, the motion of conducting fluids, and applications of MHD waves.

Outcomes:

Students will be able to describe fluid flow and apply key equations to solve fluidmechanics problems.Students will understand how gases behave at high speeds, including shock waves and Mach numbers, and solve related problems.Students will analyze the motion of charged particles in various fields and understand related phenomena.Students will understand the Compton effect and different types of fluid instabilities,applying this knowledge to practical scenarios.Students will explain interactions between magnetic fields and conducting fluids andapply MHD concepts to real-world problems.

3. AS 203: Stellar Spectroscopy & Atmosphere

Objectives:

Learning of stellar spectra and stellar radiations with its applications.Study of variation of stellar luminosities with stellar classes and life cycle of a starTo know the effect of temperature on stellar spectra and basics of its quantitativeanalysis Understand methods of observing spectral variations and its applications. To study the importance of stellar magnetic fields, stellar populations and theirclassification.

Outcomes:

The course describes the science of spectra of stars and its relation to the interiors of stars.

4. AS 204: Stellar Structure & Evolution

Objectives:

To understand the basic theory of stellar origin, structure and evolution, and introduction to compact objects. To build strong mathematical foundation on developing stellar structure equations and use them to understand the existing stellar evolution models, including the compact objects with matter in degenerate state.

Outcomes:

Students should be able to –

Critically examine the physical processes occurring in stars and how these processes affect the origin and evolution of stars.Represent the structure and evolution of stellar objects in terms of mathematical models and interpret them under different cases.Interpret the evolution of stars of different masses, from pre-main sequence to end stage of stellar life cycle, using the fundamental equations and stellar models.Understand the significance of models using degenerate state of matter in explaining the existence of compact objects.Synthesize complex mathematical information in the stellar models and communicate conclusions in clear language.

Practicals

1. AS Pr 251: Photometry and Spectroscopy using IRAF

Objectives:

Impart the knowledge of various tools and techniques used in IRAF to reduce and analyse astronomical data obtained through photometric and spectroscopic observations.

Outcomes:The students will be capable of –
Independently reduce and analyse photometric and spectroscopic data using standard procedures of IRAF.Drafting the report for the lab work performed in a suitable technical format.

2. AS Pr 252: Practical Astronomy and Astronomical Data Analysis using software applications

Objectives:
Provide the basic definitions and fundamental concepts. Learn the features and method of using the features of various astronomical data analysis applications like Vireo and Astro ImageJ/SalsaJ6.

Outcomes:Students should be able to -
Identifythe features of Celestial sphere and Constellations. Interpret various astronomical measurement parameters. Determine period of rotation of the sun using virtual observatory
Plot HR Diagram of star clusters for the given data.Process astronomical imaging dataand interpret it using Astro ImageJ / SalsaJ6. Understand basic concepts of astronomy in stellar and binary systems and analyse their data using NAAP. Draft a lab report in a systematic and technical way to represent the data collected, analysis method used and results derived.

SEMESTER III

Theory

1. AS 301: Astronomical Techniques

Objectives:
This course introduces the learners to basic instrumentations that used in astrophysical studies. It gives an in-depth exposure to working of various types of astronomical telescopes, both ground and space based. Discuss the some of the results from space based astronomical telescopes. The learners will understand the working of detectors. It gives conceptual understanding of photometry and spectroscopic techniques in astronomical studies. At the end of the course, the learners will have the ability to work with photometric and spectroscopic data. The learners will have the capacity to appreciate and understand the strength and applications of Radio astronomical techniques. They will be able to gain insight on working of Radio telescope receivers.

Outcomes:
At the end of the course, the learners will be able to work with optical telescopes and also appreciate the purpose and strength of space telescopes. The learners will have the ability to work with photometric and spectroscopic data.

2. AS 302: Advance Astrophysics

Objectives:
Thispaper gives an in-depth exposure to the concepts and methods of modern astrophysical research at the forefront of astrophysical and plasma science, with the focus on high energy

phenomenon, relevant to understanding the origin and evolution of Sun and other stellar and compact objects. The objectives also include understanding the theoretical foundations of pulsation studies of Sun and stellar objects and using it to evaluate their properties.

Outcomes:Students should be able to -

Understand and explain the physical principles underlying complex theoretical topics in astrophysicsand plasma physics/high energy physics.Search information from appropriate sources to identify the important physical processes governing astrophysical phenomena.Connect the fundamental concepts learnt in the advanced astrophysics to understanding the structure and evolution of the Sun, stellar and compact objects.Synthesize complex astrophysical information and communicate conclusions in clear language.

3. AS 303: Elective-1. A. Astrostatistics

Objectives:

Observation and theoretical Astronomy and Astrophysics results in huge amount of data and the correct interpretation requires various in-depth statistical tools in order to arrive at proper conclusion. After completion of this course, you will be able to correctly interpret noisy data. You will be able to design and apply statistical methods to answer scientific questions. You will be able to measure parameters, discover astronomical objects, or discover elusive signals in noisy data. The course will help you in cultivating Problem solving skills, recognizing and analyzing problems, solution-oriented thinking, critical thinking (asking questions, check assumptions), Analytical skills, analytical thinking, abstraction, evidence, Creative resourcefulness, curiosity, thinking out of the box.

Outcomes:

Recognize the data and apply appropriate distributions to quantify the singal and noise. Interpretation of the signals in noisy data which allow to get the physical picture of the phenomena.Reject theories which are incompatible with data.Design own statistical methods to analyze complex data.Categorize astronomical objects.Concepts and tools to perform Machine learning algorithm eg. supervised and unsupervised algorithms.Discover prejudices in analyses.
Would be able to write algorithms in python.

(OR) B. Machine Learning and Deep Learning

Objectives:

The objective of this project is to develop and implement a Machine Learning concepts and framework for predicting patterns in the data. In this course we will start with traditional Machine Learning approaches, e.g. Bayesian Classification, Maximum Likelihood method Multilayer Perceptron , Support Vector regression (SVM), Random forest method and eventually learn the application for supervised and unsupervised learning. Later move to modern Deep Learning architectures like Convolutional Neural Networks, Autoencoders etc. We will learn about the building blocks used in these Deep Learning based solutions. Specifically, we will learn about feedforward neural networks, convolutional neural networks, recurrent neural networks and other mechanisms. On completion of the course students will acquire the knowledge of applying Machine and Deep Learning techniques to solve various real-life problems.

Outcomes:

Understand the concepts of Machine Learning.Learn the underlying statistical method to implement machine learning algorithms.Able to quantity the patterns underlying the data.Would be able implement supervised and unsupervised learning.Use Clustering methods in Machine leaning algorithms.Explore the Deep learning concept and their application in astronomy and astrophysics.

4. AS 304: Elective-2. A. Electronics

Objectives:

Learn the concepts of analog and digital electronics for use in various applications.

Outcomes:Students should be able to –

Reflect on various concepts in analog and digital electronics related to various passive and active devices with an emphasis on their applications.

(OR) B. Radio Astronomy

Objectives:

Students will be familiar with radio astronomy fundamentals, theories of generation of waves,solar radio astronomy, galactic radio astronomy and extra-galactic radio astronomy.

Outcomes:

Upon successful completion of the course, the student:

Unit-I: will learn about radio window of electromagnetic spectrum, nature of radio signal,discrete radio sources of thermal and non-thermal radiation, brightness temperature, antennatemperature and noise temperature.

Unit-II: will learn about radio emission mechanisms: Bremsstrahlung, gyro-synchrotronradiation, and plasma radiation, wave polarization, Poincare sphere and Stoke's parameters.

Unit-III: will learn about Solar Radio Emissions: quiet sun radiation, slowly varying component,and solar radio bursts at different wavelengths association with flares.

Unit-IV: will learn about galactic disk radio component, HII regions and supernovae remnants,21-cm hydrogen line, CO and OH line radiations. Spiral structure of the galaxy, pulsars andenergy losses

Unit-V: will learn about CMBR, radio galaxies, AGN's, QSO's and Quasars.

Practicals

1. AS Pr 351:Electronics

Objectives:

Learn building circuits related to analog and digital electronics for use in various applications.

Outcomes:Students will be able to –

Build various analog and digital electronics circuits and evaluate their function.

2. AS Pr 352: Spectroscopy

Objectives:

Understand types of spectra and decoding the spectra. Virtually observe and analyse spectra. Understand importance of spectroscopy in studying celestial objects.

Outcomes:

The course will provide understanding in the area of spectroscopy which is one of the mostcommon and useful techniques in observational astronomy.

3. AS Pr 353: Seminar

Objectives:

To enable students to improve their knowledge and understanding of a topic assigned.

Outcomes:

It will improve students in their :

1. Presentation Skills · 2. Discussion Skills · 3. Listening Skills · 4. Argumentative Skills and Critical Thinking 5. Questioning.

SEMESTER IV

Theory

1. AS 401: Space Physics

Objectives:

Students will be familiar with, origin of the Earth's atmosphere and its lower, middle and upperatmospheric layers chemical compositions variations with respect to height and comparisonswith other planets atmospheres in the solar system, formation of the ionosphere and its studies bydifferent techniques, spectrum of solar radiation, radiation laws, scattering of solar radiations, the

solar wind, the heliospheric magnetic field, the solar wind's interaction with the Earth'smagnetic field and interplanetary atmospheres, the formation of the magnetosphere, andmagnetospheric structure, the effects of solar-variability on solar-terrestrial relations.

Outcomes:

Upon successful completion of the course, the student:

Unit-I: will learn about the origin and formation of the Earth's atmosphere and variation ofdensity, pressure and temperature in different atmospheric layers. Also learn greenhouse gases,atmospheric aerosols and comparative study of atmospheric properties of Venus and Mars.

Unit-II: will learn about the composition and structure of Stratosphere and Mesosphere,Stratospheric ozone chemistry, formation and structure of the ionosphere,

Unit-III: will learn about the spectral distribution of solar radiation, Radiation law's, Absorptionand scattering of solar radiation, Estimation of Solar Irradiance at upper Atmosphere, Rayleighand Mie scattering.
Unit-IV: will learn about solar wind, streams of solar wind, observations of solar wind and itsinteraction with planetary atmospheres.
Unit-V: will learn about Solar Terrestrial Relationships: Structure of the bow shocks,Geomagnetic storm, sub-storms, Magnetic reconnection processes, radiation belts, Aurorae.

2. AS 402: Binary stars

Objectives:

Explain the importance of binaries in the context of the determinationof basic stellar parametersDerive the orbital elements of binary starsUnderstand and explain the role of binarity in the chemical properties of somebinaries. Outline the role of compact binaries as test laboratories of general relativity

Outcomes:

The course will provide the necessary understanding of the basic physics of binary starsand the importance of binary stars and populations of binaries to modern astrophysics.

3. AS 403: Elective A. The Milky Way Galaxy & ISM

Objectives:

The Universe is composed of billions of separate collections of stars known as galaxies, and our some galaxy is an example of the spiral type of galaxy. Our Sun is located in the outer reaches of the Milky Way Galaxy and is one of the several hundred billion stars that comprise this typical spiral. In this course we will study the parts of the Milky Way Galaxy: the halo, the disk, and the central bulge. The views of our galaxy in different wavelengths will be illustrated and he resulting evolution of our perception of our home galaxy will be discussed. How to model a galaxy would studied and various perspectives are explored. The concept of dark matter and its role in the dynamics of our galaxy will be introduced. Apart from this we will study the interstellar matter, it detection techniques, how it change the view of universe.

Outcomes:

Sketch the Milky Way galaxy in an edge-on and overhead view and indicate our Sun's position.Discuss how our perceptions concerning our galaxy (and our place in it) have changed through the centuries.Describe the various components of the visible matter of the Milky Way galaxy.Give the evidence that indicates there is a dark matter halo surrounding our galaxy.List the evidence that suggests our galaxy is a spiral type galaxy.Show how self sustaining star formation could also lead to a spiral arm pattern.Discuss the components of the interstellar medium within the Milky Way.Modeling the galaxy with various physical components.

(OR) B. Galaxies & Universe

Objectives:

Explore various classifications of the galaxies based on various parameters. Mass determination methods would be explored. How the different states of gases are distributed in the galaxies and their detection techniques would investigated. Properties of galaxies are constrained based on the dynamical properties. Star formation and how their occurance rates varies in different type of galaxies will be understood. Different types of active galaxies, their emission mechanisms, association with their super massive black holes and their importance will be probed. Observational and theoretical foundation of cosmology will be envisioned.

Outcomes:

Student will gain an in-depth understanding of Classification, mass determination and distance of galaxies.Various properties of galaxies based on the observation techniques would be understood.Students would be able to determine the distribution of various states of gases in galaxies and how they are used to map the various component of galaxies. Knowledge shall be acquired on the Rotation curve and various physical elements of both spiral and elliptical galaxies.How star form in different type of galaxies and active galaxies and their classification would enable the students to compute and visualize the various aspects of these sources. Concepts of cosmology, underlying evidences and theory will help student to built a strong foundation to understand the Universe and its evolution

<u>Practicals</u>

1. AS Pr 451: Photometry

Objectives:

To train students to understand the photometric data and its significance in astronomical research. Train them to reduce and analyse the photometric data using various experimental techniques and obtain fruitful results.

Outcomes:

The students learn to reduce and analyse the photometric data of astronomical objects. And present the results in scientific way to assess the nature of the data and the object in study.They learn to draft the scientific report on the same.

2. AS Pr 452: Sky Observations

Objectives:

Provide in depth knowledge of practical astronomy performed using naked eye observations as well as different telescopes and imaging devices. Plan and conduct practical observations for both day and night time observations to understand various concepts learnt in the theoretical courses.

Outcomes:Students should be able to -

Identify and understand the evolution of celestial sphere with naked eye observations.Plan and conduct day and night sky observations.Master the identification, imaging and study of celestial objects using 12 inch Meade telescope and its accessories.Draft the report on the work performed in systematic and technical format to represent the data collection, analysis and results effectively.

3. AS Pr 453: Project Work

Objectives:

To define the problem of the proposed research work. To apply the concepts learned in course to solve the research problem. To demonstrate and validate the results of the chosen research problem

Outcomes:

Able to identify and formulate research problem. Able to design and develop solution to the problem. Able to plan, implement and execute the project. Able to write effective technical report and demonstrate through presentation

M.Sc. ASTROPHYSICS

SEMESTER III

Theory

1. AP 301: Basic Astronomy

Objectives:

Describe the primary constituents of the Universe on scales from the solar systemto observational frontiers, and place these constituents in context with theappropriate measures of space and time.Connect observations of the Universe with the fundamental laws and principles that govern the behaviour of the physical world.Learn the history of modern observational astronomy, with a key focus on how theinterpretation of results from experimentation and observation guided thedeployment of astronomy.Explore the objects that comprise the solar system, with focus on chemical andatmospheric composition and how these interact to determine the changing natureof planetary environments.

Outcomes:

The course helps to understand the observed properties of physical systems that comprise theknown universe, on various scales and exploring nature of celestial objects.

2. AP 302: Advance Astrophysics

Objectives:

Thispaper gives an in-depth exposure to the concepts and methods of modern astrophysical research at the forefront of astrophysical and plasma science, with the focus on high energy phenomenon, relevant to understanding the origin and evolution of Sun and other stellar and compact objects. The objectives also include understanding the theoretical foundations of pulsation studies of Sun and stellar objects and using it to evaluate their properties.

Outcomes:Students should be able to -

Understand and explain the physical principles underlying complex theoretical topics in astrophysicsand plasma physics/high energy physics.Search information from appropriate sources to identify the important physical processes governing astrophysical phenomena.Connect the fundamental concepts learnt in the advanced astrophysics to understanding the structure and evolution of the Sun, stellar and compact objects.Synthesize complex astrophysical information and communicate conclusions in clear language.

3. AP 303: Elective-1. A. AstroStatistics

Objectives:

Observation and theoretical Astronomy and Astrophysics results in huge amount of data and the correct interpretation requires various in-depth statistical tools in order to arrive at proper conclusion. After completion of this course, you will be able to correctly interpret noisy data. You will be able to design and apply statistical methods to answer scientific questions. You will be able to measure parameters, discover astronomical objects, or discover elusive signals in noisy data. The course will help you in cultivating Problem solving skills, recognizing and analyzing problems, solution-oriented thinking, critical thinking (asking questions, check assumptions), Analytical skills, analytical thinking, abstraction, evidence, Creative resourcefulness, curiosity, thinking out of the box.

Outcomes:

Recognize the data and apply appropriate distributions to quantify the singal and noise. Interpretation of the signals in noisy data which allow to get the physical picture of the phenomena.Reject theories which are incompatible with data.Design own statistical methods to analyze complex data.Categorize astronomical objects.Concepts and tools to perform Machine learning algorithm eg. supervised and unsupervised algorithms.Discover prejudices in analyses.
Would be able to write algorithms in python.

(OR) B. Machine and Deep Learning

Objectives:

The objective of this project is to develop and implement a Machine Learning concepts and framework for predicting patterns in the data. In this course we will start with

traditional Machine Learning approaches, e.g. Bayesian Classification, Maximum Likelihood method Multilayer Perceptron , Support Vector regression (SVM), Random forest method and eventually learn the application for supervised and unsupervised learning. Later move to modern Deep Learning architectures like Convolutional Neural Networks, Autoencoders etc. We will learn about the building blocks used in these Deep Learning based solutions. Specifically, we will learn about feedforward neural networks, convolutional neural networks, recurrent neural networks and other mechanisms. On completion of the course students will acquire the
knowledge of applying Machine and Deep Learning techniques to solve various real-life problems.

Outcomes:

Understand the concepts of Machine Learning.Learn the underlying statistical method to implement machine learning algorithms.Able to quantity the patterns underlying the data.Would be able implement supervised and unsupervised learning.Use Clustering methods in Machine leaning algorithms.Explore the Deep learning concept and their application in astronomy and astrophysics.

4. AP 304: Elective-2. A. Classical (Celestial) Mechanics

Objectives:

Students will be familiar with Newtonian and Keplerian mechanics to solve the formulations oftwo-body, three-body, Restricted three-body and N-body problems. Students will learnLagrangian and Hamiltonian formulations of mechanics of a particle and system of particles.Students will also learn the fundamental equations of rocket dynamics and interplanetary transfer
orbits.

Outcomes:

Upon successful completion of the course, the student:

Unit-I: will learn formulation and the solution of the two-body problem based on the Newtonian mechanics. And also learn Kepler’s equation and its solution.

Unit-II: will be familiar with equations of motion of three-body problem and its particular solution by Lagrangian method, Restricted three-body problem and Lagrangian points.

Unit-III: will be familiar with the equations of motion in the N-body Problem, ten integrals of motion of the n-body problem, perturbing function and virial theorem.

Unit-IV: will be familiar with Lagrangian& Hamiltonian formulation of mechanics and equations of motion of two-body problems and three body problem in Lagrangian formulation. And also learn Cyclic or ignorable coordinates and Hamilton-Jacobi partial differential equation.

Unit-V: will learn about fundamental equations of motion of a rocket in a gravitational field and in an atmosphere, Step rockets and interplanetary transfer orbits.

(OR) B. Stellar Structure and Evolution

Objectives:

To understand the basic theory of stellar origin, structure and evolution, and introduction to compact objects. To build strong mathematical foundation on developing stellar structure equations and use them to understand the existing stellar evolution models, including the compact objects with matter in degenerate state.

Outcomes:Students should be able to –

Critically examine the physical processes occurring in stars and how these processes affect the origin and evolution of stars.Represent the structure and evolution of stellar objects in terms of mathematical models and interpret them under different cases.Interpret the evolution of stars of different masses, from pre-main sequence to end stage of stellar life cycle, using the fundamental equations and stellar models.Understand the significance of models using degenerate state of matter in explaining the existence of compact objects.Synthesize complex mathematical information in the stellar models and communicate conclusions in clear language.

Practicals

1. AP Pr 351: Photometry and Spectroscopy using IRAF and Archival Data

Objectives:

Impart the knowledge of various tools and techniques used in IRAF to reduce and analyse astronomical data obtained through photometric and spectroscopic observations and the archival databases.

Outcomes:The students will be capable of –

Independently reduce and analyse photometric and spectroscopic data using standard procedures of IRAF.Drafting the report for the lab work performed in a suitable technical format.

2. AP Pr 352: Computer Applications using Python

Objectives:

To impart the knowledge of various techniques in numerical methods for finding the numerical solutions to the problems, including applications in Astronomy. Learn the concepts of python programming language for wide variety of technical applications, including the concepts learnt in the numerical methods for applications in Astronomy.

Outcomes:The students will be capable of –

Solving the given problems using numerical methods and execute the same through the python programming. Writing independently codes in python for computations as well as plotting the results.Drafting the report for the lab work performed in a suitable technical format.

3. AP Pr 353: Seminar

Objectives:

To enable students to improve their knowledge and understanding of a topic assigned.

Outcomes:

It will improve students in their:
1. Presentation Skills · 2. Discussion Skills · 3. Listening Skills · 4. Argumentative Skills and Critical Thinking 5. Questioning.

SEMESTER IV

Theory

1. AP 401: Space Physics

Objectives:

Students will be familiar with, origin of the Earth's atmosphere and its lower, middle and upperatmospheric layers chemical compositions variations with respect to height and comparisonswith other planets atmospheres in the solar system, formation of the ionosphere and its studies bydifferent techniques, spectrum of solar radiation, radiation laws, scattering of solar radiations, thesolar wind, the heliospheric magnetic field, the solar wind's interaction with the Earth'smagnetic field and interplanetary atmospheres, the formation of the magnetosphere, andmagnetospheric structure, the effects of solar-variability on solar-terrestrial relations.

Outcomes:

Upon successful completion of the course, the student:

Unit-I: will learn about the origin and formation of the Earth's atmosphere and variation ofdensity, pressure and temperature in different atmospheric layers. Also learn greenhouse gases,atmospheric aerosols and comparative study of atmospheric properties of Venus and Mars.

Unit-II: will learn about the composition and structure of Stratosphere and Mesosphere,Stratospheric ozone chemistry, formation and structure of the ionosphere, Unit-III: will learn about the spectral distribution of solar radiation, Radiation law's, Absorptionand scattering of solar radiation, Estimation of Solar Irradiance at upper Atmosphere, Rayleighand Mie scattering.

Unit-IV: will learn about solar wind, streams of solar wind, observations of solar wind and itsinteraction with planetary atmospheres.

Unit-V: will learn about Solar Terrestrial Relationships: Structure of the bow shocks,Geomagnetic storm, sub-storms, Magnetic reconnection processes, radiation belts, Aurorae.

2. AP 402: Astronomical Techniques

Objectives:

This course introduces the learners to basic instrumentations that used in astrophysical studies. It gives an in-depth exposure to working of various types of astronomical telescopes, both ground and space based. Discuss the some of the results from space based astronomical telescopes. The learners will understand the working of detectors. It gives conceptual understanding of photometry and spectroscopic techniques in astronomical studies. At the end of the course, the learners will have the ability to work with photometric and spectroscopic data. The learners will have the capacity to appreciate and understand the strength and applications of Radio astronomical techniques. They will be able to gain insight on working of Radio telescope receivers.

Outcomes:

At the end of the course, the learners will be able to work with optical telescopes and also appreciate the purpose and strength of space telescopes. The learners will have the ability to work with photometric and spectroscopic data.

3. AP 403: Elective-1 A. The Milky Way Galaxy & ISM

Objectives:

The Universe is composed of billions of separate collections of stars known as galaxies, and our home galaxy is an example of the spiral type of galaxy. Our Sun is located in the outer reaches of the Milky Way Galaxy and is one of the several hundred billion stars that comprise this typical spiral. In this course we will study the parts of the Milky Way Galaxy: the halo, the disk, and the central bulge. The views of our galaxy in different wavelengths will be illustrated and the resulting evolution of our perception of our home galaxy will be discussed. How to model a galaxy would studied and various perspectives are explored. The concept of dark matter and its role in the dynamics of our galaxy will be introduced. Apart from this we will study the interstellar matter, it detection techniques, how it change the view of universe.

Outcomes:

Sketch the Milky Way galaxy in an edge-on and overhead view and indicate our Sun's position.Discuss how our perceptions concerning our galaxy (and our place in it) have changed through the centuries.Describe the various components of the visible matter of the Milky Way galaxy.Give the evidence that indicates there is a dark matter halo surrounding our galaxy.List the evidence that suggests our galaxy is a spiral type galaxy.Show how self sustaining star formation could also lead to a spiral arm pattern.Discuss the components of the interstellar medium within the Milky Way.Modeling the galaxy with various physical components.

(OR) B. Galaxies & Universe

Objectives:

Explore various classifications of the galaxies based on various parameters. Mass determination methods would be explored. How the different states of gases are distributed in the galaxies and their detection techniques would investigated. Properties of galaxies are constrained based on the dynamical properties. Star formation and how their occurance rates varies in different type of galaxies will be understood. Different types of active galaxies, their emission mechanisms, association with their super massive black holes and their importance will be probed. Observational and theoretical foundation of cosmology will be envisioned.

Outcomes:

Student will gain an in-depth understanding of Classification, mass determination and distance of galaxies.Various properties of galaxies based on the observation techniques would be understood.Students would be able to determine the distribution of various states of gases in galaxies and how they are used to map the various component of galaxies. Knowledge shall be acquired on the Rotation curve and various physical elements of both spiral and elliptical galaxies. How star form in different type of galaxies and active galaxies and their classification would enable the students to compute and visualize the various aspects of these sources. Concepts of cosmology, underlying evidences and theory will help student to built a strong foundation to understand the Universe and its evolution

Practicals

1. AP Pr 451: Astronomical Distance Estimation and GNU plot

Objectives:

The aim of the paper is to introduce the Gnuplot program to students and teach them to use this flexible, universal and free tool to produce various graphs from data. This capability can then be applied within other courses where they need to produce graphs and also later in applied research.

Outcomes:The students will be capable of –

UseGNUplot program to produce graphical representation of given data in the desired format. Create best fit theoretical plot and functions for the data used in the plot.Draft the report on the work performed in systematic format to represent their work effectively.

2. AP Pr 452: Sky Observations

Objectives:

Provide in depth knowledge of practical astronomy performed using naked eye observations as well as different telescopes and imaging devices. Plan and conduct practical observations for both day and night time observations to understand various concepts learnt in the theoretical courses.

Outcomes:Students should be able to -

Identify and understand the evolution of celestial sphere with naked eye observations.Plan and conduct day and night sky observations.Master the identification, imaging and study of celestial objects using 12 inch Meade telescope and its accessories.Draft the report on the work performed in systematic and technical format to represent the data collection, analysis and results effectively.

3. AP Pr 453: Project Work

Objectives:

To define the problem of the proposed research work. To apply the concepts learned in course to solve the research problem. To demonstrate and validate the results of the chosen research problem

Outcomes:

Able to identify and formulate research problem. Able to design and develop solution to the problem. Able to plan, implement and execute the project. Able to write effective technical report and demonstrate through presentation

<u>COURSE OBJECTIVES AND OUTCOMES</u>

M.Sc. ASTRONOMY/ASTROPHYSICS

Objectives:

The Course helps students to develop a conceptual understanding of physics and astrophysics of space and all celestial bodies including galactic and extra galactic sources.

They study the scientific techniques in collecting and analysing the data in all bands of electromagnetic spectrum to interpret quantitative observations of celestial objects and understand theoretical models for the same.

Outcomes:

Develop research and hands-on approach that develop skills and knowledge in the latest advances in astronomy and astrophysics.
Develop mathematical and analytical skills in the various branches of sciences and gain problem solving potential in current Astronomy and Astrophysical research areas.

Overall Program Outcomes

- Students will acquire in-depth knowledge and understand the basic fundaments of Astronomical concepts.
- Students will be able to conduct observational experiments using the appropriate techniques on their own to understand the nature behavior celestial objects.
- The students will be given hands-on training on practical aspects of astronomical techniques while enhancing their knowledge of basic astronomical concepts.
- They will also be given first hand exposure to the observational instrumentations, observation methods and analysis tools.
- They can apply the basic knowledge of mathematics and physical principles to solve the mysterious of universe. Students will be able to handle a 12" inch telescope and shall be able to perform imaging and spectroscopy.
- Students will be able to write codes in python to collect the data and analyze it in order to get relevant information.
- Students will be able to extract and analyze the space satellite data to perform imaging and spectroscopy which help them to discover new astrophysical phenomenon and features.
- Machine learning codes can be written to analyze big data and characterize Astrophysical variability.
- They will be able to read, write research papers and fine tune themselves for any research group in India or abroad.
- Students will be trained in big data developing machine learning codes and implementation of artificial intelligence to constrain the variability of celestial sources via photometric imaging.
- Students will be trained in writing pipeline codes for data collection from space observatories eyeing multi-wavelength from X-ray to Gamma domain.
- Hands-on experience on large 2-m telescope will be provided which will help them in their future research career.
- Students will be trained in planning and conducting observations of various celestial objects using 12inch telescope and accessories (CCD imagers, filters and spectroscopes).
- Students will conduct the long-term sunspot observations using 3 and 6 inch telescopes equipped with neutral density filter and imager