

School of Astronomy

Prospectus for M.Sc. in Space Science and Astronomy

The M.Sc. in Space Science and Astronomy at Aryabhata Knowledge University is a two year or 4-semester postgraduate degree structured under the Choice Based Credit System (CBCS). The Syllabus covers a comprehensive range of topics in space science and astronomy including core and elective courses across four semesters:

Space Science and Astronomy are closely related fields focused on understanding the universe beyond the Earth.

The study of space includes the exploration of space, the application of scientific principles to space related technologies and the study of space-related phenomena.

Astronomy primarily studies celestial objects and phenomena, while space science encompasses the broader study of space including its exploration and the application of scientific principles to space related endeavors.

Astronomy focuses observing and understanding celestial objects like stars, planets, galaxies and nebulae, as well as phenomena like black holes and cosmic microwave background radiation. It employs telescopes (both ground based and space based), mathematical modeling and computer simulations to study the universe.

The university has been established in the name of Aryabhata (476-552 AD) who was the first of the major mathematician Astronomers from the classical age of Indian Mathematics and Indian astronomy.

Modern science starts with the keen observation of space by Galileo, (1564-1642), Kepler (1571-1630) and gravitational laws of Newton (1642-1726).

Unsolved Problems in Astronomy:

Several Significant Unsolved problems remain in Space Science and Astronomy. They are:-

- i. The nature of dark matter and dark energy
- ii. The formation and evolution of galaxies.
- iii. The search for life beyond the earth
- iv. The behavior of black holes
- v. The formation of stars and planets
- vi. The Hawking radiation which has never been observed directly
- vii. The supernova explosions
- viii. The Sun's Corona
- ix. Cosmic Rays
- x. The origin of Cosmic Magnetic Field
- xi. Radio bursts
- xii. The solar cycle
- xiii. The shape of the universe

- xiv. The origin of WOW signal, a strong signal but of a narrow band lasted for 72 seconds on August 15, 1977

1 ELIGIBILITY FOR ADMISSION

1.1 M.Sc., The eligibility conditions given below are the absolute minimum:

- i Following category of students will be eligible for admission in M.Sc. Space Science and Astronomy (SSA).
 - (a) Physics Hons.
 - (b) Chemistry Hons. With Physics and Mathematics
 - (c) Mathematics Hons.
 - (d) Geology Hons. With physics and Mathematics at B.Sc. level
 - (e) Graduation with computer, Mathematics and Physics.
 - (f) Graduation with Geo-physics and Mathematics.
 - (g) Engineering graduates.
 - (h) Graduation Astronomy and Astrophysics Subjects.For students of general Category marks requirements will be 60% and for reserved category it will be 55%.
- ii Seats available for Admission: 10 seats for admission in M.Sc. S.S.A. The exact number of seats shall be decided and notified by the University on its website/or by advertisement.

1.2 Ph.D.:- The eligibility conditions given below are the absolute minimum:

- i The applicant must have a Master's degree in Science, Engineering/Technology/ Allied subjects/ appropriate discipline/ with 55% marks or equivalent CGPA.
- ii M.Sc./PG candidates from AKU with minimum CGPA 7.5 for general category and 7 in case of SC/STs are eligible for admission in Ph.D. (SoA) Programme without appearing in the University Ph.D. Entrance Test.
- iii Candidates with a valid GATE score or CSIR/UGC NET or NBHM tenable for the current year, along with Master degree in Allied subjects/Engineering/Technology, may be exempted from the written test requirement.
- iv Full time employees of the University and other organization such as affiliated colleges, Universities, recognized research and development centres, industries, etc. may be exempted from pre Ph.D. test. However they shall be considered for admission if they will fulfil all academic criteria for Ph.D. Programme of the University.

2 ADMISSION PROCEDURE

- i. Applications will be invited by open advertisement in all leading newspapers/ local announcement for all categories of candidates.
- ii. The call for Application will also be posted on the University website <http://akubihar.ac.in>. Each applicant will be required to submit mentioned

documents along with the completed application. Incomplete application form will be rejected.

- iii. Out of the applications received, the Center will short-list the candidates to be called for written test and interview to be conducted at the University on a pre-announced date.
- iv. The syllabus for admission Test would be specified,
- v. The syllabus standard should be at B.Sc. level.
- vi. Admission test would be of 200 marks consisting of the following subjects
 - (a) Physics -100
 - (b) Chemistry – 100
 - (c) Mathematics – 100

Students can opt any two subjects out of the above three.

- vii. Questions to be asked would be of following type
 - (a) Objective
 - (b) Descriptive
- viii. Selection will be made on the basis of candidate's performance in the test examination and in the interview.
- ix. Lateral entry of students in Semester – III.
 - (a) This facility will be available to those who have completed one year diploma after graduation in the concerned subjects (Physics/Math/Chemistry).
 - (b) Those who have completed 4 Year Hons. Course in the concerned subjects.
 - (c) The selection process will be similar to that organized for admission in the 1st semester i.e. through entrance test and interview.
 - (d) No. of seats in this category would be 1% of the total strength sanctioned in the form of additional seats.
- x. BoS shall constitute Centre Selection Committee for one year starting from first of September every year for selection of the candidates, belonging to different categories, viz., Sponsored, Regular, QIP, etc. All admissions shall be made only after approval of Vice chancellor on the recommendations of the duly constituted Centre Selection Committee (CSC) and Chairperson, BoS. The CSC shall consist of at least four faculty members, at least one of whom shall be from another centre/interdisciplinary programme. The constitution of the selection committee shall be proposed by the BoS and approved by Chairperson, PGRC.

- xi. A selected candidate, who has completed all the examinations including project/thesis examination and the viva voce before the date of registration but is unable to produce the certificate in proof of having passed and secured the minimum specified qualifying marks, may be considered for provisional admission. However, if admitted provisionally, he/she shall be required to produce the evidence of his/her having passed (or at least appeared in) the qualifying degree examination by the last date as fixed by the University, failing which the admission may be cancelled.
- xii. On approval by the Vice-Chancellor, the Head of the Centre will issue the admission letters to the candidates, who may accept the offer of admission by depositing the prescribed fee before the specified date.
- xiii. In case a candidate does not accept the offer by paying the prescribed fee by the specified date, the offer of admission may stand withdrawn, and the admission may be offered to the candidates in the waiting list, if any, in order of merit.
- xiv. The offer of admission may also stand withdrawn if the candidate who has accepted the offer fails to register by the date for last registration.
- xv. Prior to putting an advertisement for admitting Ph.D. students, SoA will compile information regarding available slots of each supervisor; his/her respective areas of work etc. and make it available for inclusion into admission information brochure. The short-listing of applications for the purpose of admission will be done by the BoS, SoA.
- xvi. If considered necessary, the BoS of the SoA may set the short listing criteria higher than the minimum eligibility defined at under aforementioned section for Ph.D. admission eligibility and take prior approval of chairperson, PGRC, before admission/selection process is initiated.
- xvii. Reservation policy as prescribed by Government of Bihar/Deptt. Of Education from time to time shall be applicable.

3 ADMISSION OF CANDIDATES UNDER QUALITY IMPROVEMENT PROGRAMME FOR Ph. D.

Teachers in Engineering/Academic institutions will get an opportunity to study at AKU under the quality **improvement** programme (QIP). Teachers will continue to remain as employees of their college during the period of study at AKU. The FIP will be similar to QIP but will apply to teachers in private engineering institutions. These candidates

will have to satisfy the prescribed minimum marks and qualification as laid down in section 6.4.

4 ADMISSION OF INDIAN NATIONALS RESIDING ABROAD (INRA), DIRECT ADMISSION OF STUDENTS ABROAD (DASA) AND FOREIGN NATIONALS

- i. INRA candidates must have been residing abroad continuously for at least three years at the time of applying for admission. Their applications may be processed by the CSC as and when they are received or according to any schedule convenient to the Centre. The applications should be scrutinized to make sure that, both in terms of qualifications and attainment; they are comparable with the candidates admitted in the general category.
- ii. The applications of foreign nationals, who are sponsored by the Indian Council of Cultural Relations (ICCR)/MHRD will be scrutinized by BoS of the Centre to assess their suitability for admission to the programme. The Centre's Board of Studies recommendation shall be sent to the Vice-Chancellor.
- iii. The applications of non-sponsored foreign national candidates will also be considered for admission to the postgraduate programmes by BoS, SoA. Such candidates who are in India and are seeking admission to the M.Tech. Programme must satisfy the same requirements (if eligible to take it) as the candidates in the general category. However, application of a candidate who is in India and has not been able to take entrance test for valid reason will be considered by the CSC concerned on its merit.

5 ADMISSION OF SPONSORED CANDIDATES

- i A candidate who is sponsored for either Full time (FT) or Part time (PT) studies at AKU by his/her employer and who meets the additional conditions specified below may be admitted through the CSC.
- ii A sponsored candidate must have minimum relevant experience of two years, and must have been in service of the sponsoring organization for at least one year at the time of admission. The sponsoring organization must specifically undertake to relieve him/her to pursue the programme for its full duration. The sponsored candidates will be required to submit No Objection Certificate (NOC) from their employer/ organization stating that:

His/her official duties permit him/her to devote sufficient time for M.Tech./Research. Candidate should give undertaking that he would fulfill the attendance requirements of all the courses undertaken by him for fulfillment of the course pursued.

6 ADMISSION OF NON-DEGREE STUDENTS

- i A non-degree student is a student who is registered for a degree in any other recognized University or university in India or abroad, and who is officially sponsored by that University or university to complete part of his/her academic requirements at AKU. For that purpose, the non-degree student may carry out Research/Course work/and use other academic facilities as agreed upon in MoU with those Universities/Organizations.
- ii The strength of non-degree students in any programme should not be more than 5% of the programme strength.

Students so admitted will be governed by all rules, regulations and discipline of the University.

Aryabhatta Knowledge University, Patna

School of Astronomy

The syllabus for M. Sc. in Space Science and Astronomy (SSA) semester-wise course Scheme of Instruction and Examination (w. e. f. the academic year 2025-2026) Proposed Choice Based Credit System – (CBCS)

1. This course will be of four semester duration open to first and second class B.Sc.'s with Physics and Mathematics as two optional.
2. Admission will be based on merit in the Entrance Test conducted by the University along with the roster system applicable in the University.
3. Semester wise theory and practical courses to be taken during the four semesters of M.Sc. is listed below:

Scheme of Instruction and Examination

SEMESTER -I

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	SSA 101	Basic Physics	3	3	30 + 70	4
2	SSA 102	Mathematical Methods of Physics	3	3	30 + 70	4
3	SSA 103	Basic Astronomy	3	3	30 + 70	4

4	SSA 104	Classical (Celestial) Mechanics	3	3	30 + 70	4
PRACTICALS						
5	SSA Pr 151	Numerical Methods and Computer Applications using Python	8+8	4	100	4
6	SSA Pr 152	Data Handling using GNU plot and Astronomical Distance Estimation Techniques	8+8	4	100	4
		Total:	44		600	24

Theory Paper SSA-101: Basic Physics

Unit – I : Electromagnetic Theory

Maxwell's Equations and their derivations and integral forms. Scalar and Vector potentials, Coulomb and Lorentz gauge. Electromagnetic waves. Poynting Theorem.

Unit – II : Transformations

Canonical transformations, Conditions for canonical transformation and problem, Poisson brackets, invariance of PB under canonical transformation, Rotating frames of reference, inertial forces in rotating frames.

Unit – III : Statistical Mechanics

Entropy and Probability, Ensembles, Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. Fermi energy, Mean energy of fermions at absolute zero, Fermi energy as a function of temperature, Electronic specific heat, Bose-Einstein Condensation

Unit – IV : Special Theory of Relativity

Concept of Special Theory of Relativity, Lorentz Transformation, Length Contraction and time dilation, Relativistic addition of velocities, relation between energy and momentum

Unit – V: Applications of Relativity

Concept of General Theory of Relativity, Equivalence of mass and energy, Relativistic Doppler shift and aberration of light. Lagrangian and Hamiltonian of relativistic particles, Relativistic degenerate electron gas.

REFERENCES

1. Introduction to Electrodynamics by David Griffiths.
2. Foundations of Electromagnetic Theory by J R Reitz and F J Milford.
3. Classical Mechanics by H. Goldstein, Narosa Publishing Home, New Delhi.
4. Classical Mechanics by N. C. Rana and P. S. Joag, Tata Mc-Graw Hill Publishing Company Limited, New Delhi.
5. Introduction to Classical Mechanics by R. G. Takawale and P. S. Puranik, Tata Mc-GrawHill Publishing, Company Limited, New Delhi.

6. Classical Mechanics by J. C. Upadhyaya, Himalaya Publishing House.
7. Statistical Mechanics by K. Huang, John Wiley & Sons (2nd Edition).
8. Statistical Mechanics by Satya Prakash, KedarNath Ram Nath Publication (2008).
9. Statistical Mechanics by Loknathan and Gambhir.
10. Statistical Mechanics by Landau and Lifshitz.
11. Special Theory of relativity by Resnik.
12. The Lighter side of Gravity by J. V. Narlikar.

Theory Paper SSA -102: Mathematical Methods of Physics

Unit – I : Ordinary differential equations

Second order homogeneous and non-homogeneous differential equations with constant and variable coefficients, The Superposition Principle. Solution by power series method due to Frobenius method. Solutions of Legendre's and Bessel's differential equations.

Unit – II : Partial differential equations

Solutions by the method of separation of variables. Wave equation in one and two dimensions, Poisson's and Laplace's equations, Heat Conduction (or Diffusion) equation and their solutions. Solution of Euler's differential equation, Riccati equation.

Unit – III : Special functions

The Hermite Polynomials, One-dimensional Linear Harmonic Oscillator, Solution of Hermite's Differential Equation, Gamma, Beta, Legendre and Associated Legendre, Bessel functions of the first kind and their properties.

Unit – IV : Fourier Series

Definition of Fourier Series and expansion of a function of x . Extension of interval. Advantages of Fourier series. Complex form of Fourier series.

Unit – V : Fourier Transforms

Fourier's integrals. Fourier transform and their inverse. Transforms of Derivatives, Parseval's relation. Use of Fourier transform in solving some definite integrals.

REFERENCES

1. Shepley and Ross: Differential Equations.
2. Piper and Harvill: Applied Mathematics for Engineers and Physicists.
3. J. Irving and Mullineux: Mathematics in Physics and Engineering.
4. V. I. Awmianoc translated by D. E. Brown: A course of Higher Mathematics Vol. IV.
5. I. N. Sneddon: Fourier series.
6. Charlie Harper: Introduction to Mathematical Physics.

Theory Paper SSA-103: Basic Astronomy

Unit - I: Positional Astronomy

Identification of the objects visible in the night sky to the unaided eye: constellations and nomenclature of stars. The cardinal points and circles on the celestial sphere. Spherical triangle and related problems.

Sky coordinates and motions: Horizontal, Equatorial, ecliptic and galactic system of co-ordinates.

Unit – II: Astronomical Systems of Measurements

Seasons, Twilight, Sidereal, Apparent and Mean solar time and their relations, Equation of time, Calendar, Julian date and heliocentric correction. Effects of atmospheric refraction, aberration, parallax, precession, nutation and proper motion on the coordinates of stars.

Unit – III: Distances and Magnitudes

Distances of stars, stellar motions, parallax methods to measure distances to stars. Magnitude systems. Apparent and Absolute magnitudes and distance modulus. colour index. Atmospheric extinction.

Unit – IV: The Sun and its features

Origin of Universe-the Big Bang-Expansion of Universe, Formation and evolution of solar system. The Sun, Surface features of the sun in white and monochromatic light. Internal structure. Sun spots and magnetic fields on the sun. Solar activity.

Unit – V: Planetary physics

Planets: Their types - planet atmospheres - extra solar planets - Surface features of planets, Internal structure, Atmospheres and Magnetic fields of Planets and their moons. Results of space probes.

Minor Planets: Discovery and designation, Origin, Nature and orbits of Asteroids, Comets, Meteors and meteor showers.

REFERENCES

1. W. M. Smart: Text book of Spherical Astronomy.
2. A. E. Roy: Orbital Motion.
3. Mc Cusky: Introduction to Celestial Mechanics.
4. K. D. Abhyankar: Astrophysics: Stars and Galaxies. Tata McGraw Hill Publication (Chap.2)
5. G. Abell: Exploration of the Universe.
6. A. Unsold: New Cosmos.
7. Baidyanath Basu: An Introduction to Astrophysics
8. An Introduction to Astrophysics by Ajit Kumar Sharma.
9. The Sun by M. Stix
10. Fundamental Astronomy by H. Karttunen, H. Oja and K. J. Donner.

Theory Paper SSA-104: Classical (Celestial) Mechanics

Unit – I : The Two-Body Problem

Motion in a Central Force Field. Motion in an inverse square law force field. Kepler's Laws. Formulation of the two-body problem. Integrals of area, angular momentum, and energy. Equation of the relative orbit and its solution. Kepler's equation and its solution.

Unit – II: The Three-Body Problem

The Three-Body Problem – its equations of motion. Restricted three-body problem. Tisserand's criterion. Lagrange's solution for the motion of three bodies. Surfaces of zero

relative velocity, Lagrangian points. Double points.

Unit – III: The Many-Body Problem

The Equations of Motion in the Many-body Problem. Stability of straight line and equilateral triangle solutions. The ten integrals of motion of the n-body problem. Transfer of origin to one of the particles. The perturbing function. Virial theorem.

Unit – IV: The Lagrangian and Hamiltonian Formulation

Lagrangian & Hamiltonian formulation of Mechanics. Equations of motion in Lagrangian formulation. Mechanics of a particle in Lagrangian formulation. Equations of motion of two-body problems and three body problem in Lagrangian formulation. Cyclic or ignorable coordinates. Contact transformation, Hamilton-Jacobi partial differential equation.

Unit – V: Rocket Dynamics and Transfer Orbits

Fundamental equations of motion of a rocket. Motion of a rocket in a gravitational field and in an atmosphere. Step rockets. Minimum energy orbits. Transfer orbits. Parking orbits. Perturbations of artificial satellites due to atmospheric drag and flattening of the earth.

REFERENCES

1. H. Goldstein: Classical Mechanics, Narosa Publishing Home, New Delhi.
2. N. C. Rana: Classical Mechanics.
3. J.C. Upadhyaya: Classical Mechanics, Himalaya Publishing House.
4. R. G. Takwale and P. S. Puranik: Introduction to Classical Mechanics.
5. W. M. Smart: Text book of Spherical Astronomy.
6. A. E. Roy: Orbital Motion.
7. Mc Cusky: Introduction to Celestial Mechanics.
8. K. D. Abhyankar: Astrophysics of the solar system.
9. F. R. Moulton: An Introduction to Celestial Mechanics.
10. Danby: Fundamentals of Celestial Mechanics.

Practical Paper SSA-151: Numerical Methods and Computer Applications using Python

Part - A

1. Methods of least squares
3. Numerical interpolation: Forward, backward, central
4. Numerical differentiation and integration Trapezoidal rule, Simpson 1/3, 3/8 rules
5. Solution of ordinary differential equations using RK methods for first to fourth order DE

Part -B

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|-------------------------------------|-----------------|
| 1. Operating Systems | : UNIX / LINUX. |
| 2. Editors | : Word and vi |
| 3. Programming concepts | : Python |
| 4. Numerical Analysis using Python. | |

Practical Paper SSA -153: Data Handling using GNU plot and Astronomical Distance

Estimation Techniques

Part - A

1. Plotting 2D and 3D Data

2. Polynomial and function fitting
3. Histograms, error determinations
4. Least - Square methods and fittings
5. Correlation and Regression analysis

Part - B

1. Parallax Method
2. Main sequence method
3. Cepheids Method
4. Galaxies Red shift Method
5. Tully- Fisher relation Method

REFERENCES

1. J. B. Scarborough: Numerical Analysis.
2. R. Subramanian. P. Achutan. and K. Venkatesan (Translators): Numerical Analysis for Engineers and Physicists.
3. M. K. Jain. S. R. K. Iyengar and R. K. Jain: Numerical Methods for Scientific and Engineering Computation.
4. Python for Data Science, Alen Campbell
5. Programming Python, Mark Lutz, O'Reilly
6. Python Programming : Using problem solving approach, Reema, Thareja, Oxfor Higher Education
7. Norton's Atlas

SEMESTER -II

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	SSA 201	Quantum Mechanics	3	3	30 + 70	4
2	SSA 202	Fluid Mechanics and Magneto Hydro Dynamics	3	3	30 + 70	4
3	SSA 203	Stellar Spectroscopy & Atmosphere	3	3	30 + 70	4
4	SSA 204	Stellar Structure & Evolution	3	3	30 + 70	4
PRACTICALS						
5	SSA Pr 251	Photometry and Spectroscopy using IRAF	8+8	4	100	4
6	SSA Pr 252	Practical Astronomy and Astronomical Data Analysis using software applications	8+8	4	100	4
ADDITIONAL PAPER						
7	SSA 205	National Security Strategy	2	3	100	3

	Total:	46		700	27
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Theory Paper SSA-201: Quantum Mechanics

Unit -I: Foundation of Quantum Mechanics

Schrodinger wave equation and probability interpretation, Simple one dimensional problems – wells, barriers and harmonic oscillator (One and three dimensional), Time dependent Schrodinger equation and problems.

Unit-II: General Formalism of Quantum Mechanics

Physical interpretation of eigen values, eigen functions, eigen values, and eigen functions of momentum operator. Eigen values and eigen functions of L^2 and L_z operators, ladder operators L_+ and L_- and their operations.

Unit-III: Spin and Momentum operators

Pauli theory of spins (Pauli's matrices), Addition of angular momenta, Computation of Clebsch-Gordon co-efficients in simple cases ($J_1=1/2$, $J_2=1/2$) Central forces with an example of hydrogen atom.

Unit-IV: Approximation Theory

Time-independent Perturbation theory: Non degenerate and degenerate cases. Applications: Zeeman effect, Stark effect, Time-dependent Perturbation theory: Transition amplitude 1st and 2nd order, selection, rules, constant perturbation (1st order). Fermi's golden rule, Interaction of atom with EM radiation, dipole approx, Einstein coefficient for emissions and transition probabilities.

Unit-V: Scattering

Absorption cross-section, Differential and total cross sections, Thomson and Rayleigh scattering, Mie Scattering, Born approximation, Validity of Born Approx., Application to square well potential.

REFERENCES

1. An overview of Basic Theoretical Astrophysics by K D Abhyankar and AW Joshi, Universities Press.
2. A Text book of Quantum Mechanics by P. M. Mathews and K.Venkatesan, Tata McGraw Hill.
3. Quantum Mechanics by A. Ghatak and S. Lokanathan, Macmillan India Ltd.
4. Quantum Mechanics by L. I. Schiff, McGraw Hill.
5. Modern Quantum Mechanics by J. J. Sakurai.
6. Quantum Physics by R. Eisberg and R. Resnick (Wiley and Sons).
7. Introduction to quantum mechanics by D. I. Griffiths (Pearson Education) (IInd Edition).
8. Introductory Quantum mechanics by W. Granier, Springer Publication.
9. Introductory Quantum Mechanics by R. Liboff, 4th Edition, Pearson Education Ltd.

Theory Paper SSA -202: Fluid Mechanics and Magnetohydrodynamics

Unit -I: Fluid Mechanics

Steady and Unsteady flows, Velocity potential, Vorticity vector, equation of continuity, acceleration of fluid, Euler's equation of motion, Bernoulli's equation, circulation and Vortex motion, Kelvin's theorem, viscosity of fluid motion, Navier Stokes equation of motion of a

viscous fluid.

Unit -II: Gas Dynamics

Wave motion and its solution, speed of sound in a gas, formation of shocks, mach number, isentropic gas flows, Mach number and its dependency across the shock with pressure, density and temperature, Ram pressure, Normal shocks, Rankine -Hugoniot relations.

Unit-III: Motion of charged particles and Instabilities

Motion of charged particles in electric and magnetic field, Motion of charged particle in electromagnetic field, particle drifts in non-uniform magnetic field, Mirror effect, Adiabatic invariants.

Unit -IV: Comptonization and Instabilities

Detail study of Compton and inverse Compton effect, y-parameter, Compton spectrum Kelvin-Helmholtz instability, Rayleigh-Taylor instability.

Unit-V: Magnetohydrodynamics

Maxwell's equations (medium in motion) and its simplification, Magnetic diffusion, equation of motion of conducting fluid, fluid in motion, magnetic Reynolds number and its dimensional analysis, Alfven theorem, Magnetic body force, Magnetohydrodynamics, Pinch confinement of plasma, MHD waves and its applications.

REFERENCES

1. F. Chorlton: Textbook of Fluid Mechanics
2. Jackson: Classical theory of Radiation.
3. Oleg Glebov: Motion of Charged particles.
4. The Physics of Fluids and Plasmas: An Introduction for Astrophysicists [Arnab Rai Choudhuri](#).
5. The physics of astrophysics gas dynamics 2 (sessions of both in Astronomy) university science books (1994) [Frank Shu](#).

Theory Paper SSA-203: Stellar Spectroscopy & Atmospheres

Unit -I: Spectra of Stars

Spectral lines and Spectral types, basic ideas on spectral line formation, HR diagram, HD and MK spectral classification of stellar spectra. Explanation of stellar spectra in terms of Boltzmann and Saha equations.

Unit -II: Qualitative description of causes of spectral line Broadening

Equivalent widths, Natural damping, Collisional damping, Superposition of Doppler and damping profiles, Statistical broadening of hydrogen lines, Stark effect in helium lines, Electron pressure in early type stars.

Unit-III: Curve of Growth

Theory of the curve of growth, Application of the curve of growth to the study of solar and stellar atmospheres, Limitations of the curve of growth method.

Unit-IV: Equation of Transfer

Definitions concerning the radiation field, Equation of transfer and its formal solution, Hypothesis of plane parallel and spherically symmetric stratification, Local thermodynamic equilibrium, Radiative equilibrium, Grey approximation.

Unit-V: Abundances of Elements

Abundance of elements in sun and stars, Fine analysis-Stromgren's method, Stellar atmospheric models, Composition differences in population I and II stars, Peculiar A stars and metallic line stars, Magnetic field in stars.

REFERENCES

1. L. H. Aller: Astrophysics.
2. J. Greenstein(Ed): Stellar Atmospheres.
3. Hynek: Astrophysics.
4. Mihalas: Stellar Atmospheres.
5. E. Ambartsumian: Theoretical Astrophysics.
6. K. D. Abhyankar: Astrophysics Stars and Galaxies.
7. C. R. Kitchin: Astrophysical Techniques (4th edition).

Theory Paper SSA-204: Stellar Structure & Evolution

Unit-I: Fundamental Equations

Stellar time scales. Equation of mass distribution. Equation of hydrostatic equilibrium. Virial Theorem. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar Opacity. Eddington limit. Stellar energy sources.

Unit-II: Stellar Models

Boundary conditions (central and surface). Russell-Vogt theorem. Polytropic model. Lane-Emden equation and its solution. Properties of polytropes. Homology transformations. Dimensional analysis: Mass-Luminosity and Mass – Radius relations.

Unit-III: Stellar Evolution

Jean's criterion for gravitational contraction and its difficulties. Star forming regions. Protostars. T- Tauri stars. Brown Dwarfs. Red giants Pre-Main Sequence Evolution: Hayashi tracks and Henyey tracks. Schoenberg-Chandrasekhar limit. Main-Sequence and Post Main Sequence Evolution of stars of different masses. Eddington Luminosity. Planetary Nebulae. Ages of galactic & globular clusters.

Unit-IV: Superdense Objects - White Dwarfs

White Dwarfs. Use of Polytropic model for completely degenerate stars. Chandrasekhar Mass. Mass- radius relation for White Dwarfs. Non-degenerate upper layers and abundance of Hydrogen. Stability of White Dwarfs. Cooling mechanism in White Dwarfs. Accretion by White Dwarfs and its consequences.

Unit -V: Superdense Objects-Neutron stars and Black Holes

Supernovae, Neutron stars, Black Holes. Pressure ionization and mass-radius relation for cold bodies. Masses of Neutron stars and Black Holes.

REFERENCES

1. M. Schwarzschild: Stellar Evolution
2. R. Kippenhahn A. Weigert: Stellar Structure and Evolution
3. Dina Prialnik: An Introduction to the Theory of Stellar Structure and Evolution
4. Baidyanath Basu: An Introduction to Astrophysics.
5. S. Chandrasekhar: Stellar Structure
6. Cox and Guili: Principles of Stellar Interiors – Vol. I & II
7. Shapiro and Teukolsky: White Dwarfs, Neutron Stars and Black Holes
8. R. Bowers and T. Deeming: Astrophysics
9. Frank H. Shu: The Physical Universe

Practical Paper SSA -251: Photometry and Spectroscopy using IRAF

Part - A

1. DS9
2. Ximtool
3. Imexamine
4. Apphot
5. Photometric data archives

Part - B

1. Twodspec
2. Apextract
3. Apall
4. Wavelength calibration
5. Splot
6. Spectroscopic data archives

Practical Paper SSA-253: Practical Astronomy and Astronomical Data Analysis using Software applications

1. Basic Definitions and Fundamental Concepts
2. Identification of features of Celestial sphere and Constellations
3. Determining period of rotation of the sun using virtual observatory
4. HR Diagram of star clusters
5. Astro ImageJ / SalsaJ
6. NAAP

REFERENCES

1. Peter MB Shames, Doug Tody: A user's Introduction to the IRAF command language version 2.3
2. Frederic P. Miller Agnes F. Vandome, Mc Brewster John: IRAF, VDM Publishing, 2010.
3. Chrispin Karthick, M: Astronomical data Reduction guide.
4. Smart: Spherical Astronomy.
5. Bowuwer and Clemence: Methods of Celestial Mechanics.
6. J. Nassau: Practical Astronomy.
7. CLEA, VIREO websites (web resources).

M.Sc. Space Science & Astronomy III & IV - semester - Scheme of Instruction and Examination

SEMESTER – III

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	SSA 301	Astronomical Techniques	3	3	30 + 70	4
2	SSA 302	Advance Astrophysics	3	3	30 + 70	4
3	SSA 303	Elective-1. A. Astrostatistics (OR) B. Machine Learning and Deep Learning	3+3	3	30 + 70	4
4	SSA 304	Elective-2. A. Electronics (OR) B. Radio Astronomy	3+3	3	30 + 70	4
PRACTICALS						
5	SSA Pr 351	Electronics	8	4	100	4
6	SSA Pr 352	Spectroscopy	4	2.5	50	2
6	SSA Pr 353	Seminar	4	2.5	50	2
		Total:	34		600	24

SEMESTER - IV

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	SSA 401	Space Physics	3	3	30 + 70	4
2	SSA 402	Binary stars	3	3	30 + 70	4
3	SSA 403	Elective A. The Milky Way Galaxy & ISM (OR) B. Galaxies & Universe	8+8	3	30 + 70	4
PRACTICALS						
5	SSA Pr 451	Photometry	12 (4x3)	3	100	4
6	SSA Pr 452	Sky Observations		2.5	50	2
7	SSA Pr 453	Project Work	-	4	150	5
		Total:	34		600	23

Theory Paper SSA -301: Astronomical

Techniques Unit-I: Optical and IR Telescopes

Basic Optics, Types of telescopes- refractive, reflective and catadioptric telescopes. Telescope mounting systems. Solar telescopes. Importance of Infrared astronomy, IR telescopes, properties of IR telescopes, Major IR missions. Active and adaptive optics.

Unit-II: Space Telescopes

Importance of space based astronomy. Space Telescopes. Space based instrumentation and science, Ultraviolet Fundamentals, Ultraviolet Telescopes, Major UV space Mission, X-Ray Fundamentals, X-Ray Telescopes, Major X-Ray space Mission, Astrosat (ISRO), XMM-Newton, Chandra and Swift and their scientific results. Gamma-Ray Fundamentals, Gamma-Ray Telescopes

Unit-III: Detectors

Classification of detectors, characteristics of detectors. Detectors for optical and infrared wavelength regions. Working of Charge Coupled Device (CCD). sensitivity, noise, quantum efficiency, spectral response, Johnson noise, signal to noise ratio. Application of CCD for stellar imaging. Observational techniques of astronomical sources from space in infrared, EUV, X-ray and Gamma-ray regions of the electromagnetic spectrum.

Unit-IV: Photometry and Spectroscopy

Astronomical photometry. Observing technique with a photometer. Application of CCD for photometry. Correction for atmospheric extinction. Transformation to a standard photometric system. Astronomical spectroscopy. Application of CCD for spectroscopy.

Unit-V: Radio Astronomical Techniques

Radio window. Antenna parameters. Various types of antennas -based on steerability. construction of simple radio telescopes. Receiver systems and their calibration. Design and construction of a simple radio interferometer. VLBI Systems. Aperture Synthesis.

REFERENCES

1. C. R. Kitchen: Astrophysical Techniques (4 th edition).
2. Ian S. McLean: Electronic Imaging in Astronomy: Detectors and instrumentation (2nd ed.).
3. Steve B. Howell: Handbook of CCD Astronomy (2 nd edition).
4. A. E. Roy and D. Clarke: Astronomy Principles and Practice (Part-3, 4 th edition).
5. W. A. Hiltner (Ed): Astronomical Techniques.
6. Gordon Walker: Astronomical Observations - an Optical Perspective (CUP).
7. Henden and Kaitchuck: Astronomical Photometry.
8. C. R. Miczaika and W. M. Sinton: Tools of the Astronomers
9. Carleton: Methods of Experimental Physics. Vol. XIIA.
10. G. F. Knoll: Radiation Detection and Measurement (2nd edition).

Theory Paper SSA -302: Advance Astrophysics

Unit-I: Fundamentals for Radiations

Jefimenkas equation, Lienard-Wiechart potentials, Field of moving point charges, electrical dipole radiation in terms of potentials, power radiated by a point charge

Unit-II: Radiative processes

Ionization losses in non-relativistic and relativistic cases, radiation of an accelerated charge, its spectral distribution, Bremsstrahlung spectrum and its application in astrophysics, electron energy loss rate in uniform magnetic field, inverse Compton spectrum and its application in astrophysical sources, Sunyaev-Zeldovich effect, Synchrotron-self Compton radiation

Unit-III: Solar Dynamo

Magnetic flux freezing, Alfven theorem of flux freezing, magnetic buoyancy, Induction equation, reconnection of magnetic lines of force, toroidal and poloidal magnetic fields, Omega effect, alpha effect and connection to solar cycle, mean field dynamo theory, meridional flow, filaments/prominences, coronal loops, coronal mass ejections (CMEs), heating of corona, Parker solution of solar wind, effect of magnetic field on solar wind

Unit-IV: Fundamental of Stellar Oscillations

Equation of continuity, Equation of motion, Energy equation, Adiabatic approximation, Equilibrium structure, perturbation analysis, Acoustic waves, internal gravity waves, pulsation constant, P modes, g modes, f modes.

Unit-V: Helioseismology and Astroseismology

Basics of Helioseismology, Solar oscillation and different modes, stellar oscillations in different types of stars, Fundamental stellar parameters and their derivation using astroseismology

REFERENCES

1. Introduction to Electrodynamics: J. D. Griffiths, Cambridge University Press
2. *Radiative Processes* in Astrophysics: Rybicki and Lightman, Wiley interscience
3. High energy Astrophysics: M. S. Longair, , Cambridge University Press
4. Astrophysics for physicists: A. R. Choudhuri, Cambridge University Press
5. The Sun, An Introduction: Mechael, Springer-Verlag
6. Plasma Astrophysics: J.G. Kirk, D. B. Melrose, E. R. Priest, Springer-Verlag
7. Astroseismology: Aerts, Christensen-Dalsgaard, Kurtz, Springer
8. *The Non-Radial Oscillations* of Stars in General Relativity: S. Chandrasekhar, University of Chicago Press

Theory Paper SSA -303: Elective -1A. AstroStatistics

Unit-I: Basic Statistics

Mean, Median, Mode. Standard deviation. Concepts of probability theory, discrete and continuous random variables, bivariate probability distributions. Binomial, Poisson and Gaussian distributions.

Unit-II: Regression & Hypothesis

Correlation, regression and covariance, Testing of hypothesis –null hypothesis, alternate hypothesis, types of errors, critical and acceptance regions, level of significance.

Unit-III: Sample Testing

Large sample tests for mean(s), variances. Small sample t- tests for single mean and different mean, F distribution and F-test, Chi-square distribution. Chi-square test, Chi-square test for goodness of fitting, ANOVA - one way classification.

Unit-IV: Multivariate Data Analysis

Categorical data analysis, and model building. covariance matrix, Eigen function, Eigen values, principal components classification, discriminate analysis, Fisher method, within-class scatter matrix, between-class scatter matrix.

Unit-V: Clustering Methods

clustering, cluster linkage methods, single, complete, average and centroid linkages, distance estimation, k-means method, hierarchical clustering, dendrogram.

REFERENCES

1. Statistical Methods by S P Gupta.
2. Applied Multivariate Statistical Analysis by Richard A Johnson and Dean W Wichern.
3. An Introduction to Statistical Learning, with Applications in R by James, Witten, Hastie and Tibshirani (Springer, 2013).
4. Practical Statistics for Astronomers, Cambridge Observing Handbook for Astronomers, J V Wall.
5. Modern Statistical Methods for Astronomy: with R Applications, Eric Feigelson, G Jogesh Babu
6. Statistical Challenges in Modern Astronomy, Eds: Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber. (Elsevier)

Theory Paper SSA -303: Elective - 1B. Machine Learning and

Deep Learning Unit-I: Basic Statistics

Normal distributions, Expectation, Moments of Distribution, and Central limit theorem, Bayes theorem, Prior, Posterior, Bayes optimal classifiers, Maximum Likelihood method

Unit-II: Supervised Learning-Regression

Linear Regression, multiple linear Regressions, K-nearest neighbors, under fitting, over fitting, Support Vector regression (SVM), Random forest method.

Unit-III: Supervised Learning-Classification

Logistic regression, Principal Component Analysis, LDA, Singular Value Decomposition, Independent Component Analysis, K nearest neighbor, support vector classifier, Gradient boosting method.

Unit-IV: Unsupervised Learning

Supervised vs Unsupervised learning, learning steps, Decision tree, linkages, Hierarchical clustering, Non- Hierarchical clustering, K-means clustering, Density Based Scan Clustering (DBSCAN), Gaussian clustering model.

Unit-V: Deep learning

Regularization, convolutional neural networks (CNN): Architectures, convolution / pooling layers, recurrent neural networks: its Architectures, Back Propagation through time, variational autoencoders, generative models, applications.

REFERENCES

1. Statistical Methods by S P Gupta.
2. Applied Multivariate Statistical Analysis by Richard A Johnson and Dean W Wichern.
3. An Introduction to Statistical Learning, with Applications in R by James, Witten, Hastie and Tibshirani (Springer, 2013).
4. Practical Statistics for Astronomers, Cambridge Observing Handbook for Astronomers, J V Wall.
5. Modern Statistical Methods for Astronomy: with R Applications, Eric Feigelson, G Jogesh Babu
6. Statistical Challenges in Modern Astronomy, Eds: Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber. (Elsevier)
8. Ian Goodfellow, YoshuaBengio and Aaron Courville. Deep Learning. MIT Press 2016
9. Navin Kumar Manaswi, Deep Learning with Applications using Python, Apress, NewYork, 2018.

Theory Paper SSA -304: Elective - 2A. Electronics

Unit-I: Semiconductor Devices

CMOS, Transistor, Biasing of multi stage RC-coupled amplifier Power Supply DC voltage regulators. Concept of DC to DC converter, UPS and Inverters.

Unit-II: Feedback Amplifiers

Classification of Amplifiers. The concept of feedback, Positive and negative feedback. Advantages of negative feedback. Emitter follower. Sinusoidal Oscillators Criterion for oscillations, Phase shift, Wein bridge, Hartley and Colpitts oscillators, IC 555 Astable, Monostable and Bistablemultivibrator.

Unit-III: Operational Amplifiers

Inverting and Non-inverting Op-Amps. Concept of input/output impedance, Input bias current, Offset input voltage, Slew rate, CMMR, Gain, Frequency response, Band Width. IC 555, Applications of Operational Amplifiers: Active filters, rectifiers.

Unit-IV: Digital Electronics

BCD, Octal, Hexadecimal, ASCII, Signed binary number representation with 1's and 2's complement methods, Binary arithmetic, Boolean algebra, logic gates and circuits, adder / subtractor, encoder / decoder, comparator, multiplexer / de-multiplexer, parity generator,

combinatorial/Sequential Circuits, Flip-Flops, Counters/Registers, A/D and D/A conversion.

Unit-V: Modulation and Detection

Amplitude modulation, Frequency components in an AM signal, Balanced amplitude modulator, Envelope and Square law detectors. Frequency modulation, Frequency components in FM signal, Basic Reactance modulator, FM discriminator. Phase modulation. Introduction to Digital modulation and demodulation techniques.

REFERENCES

1. Power Supplies by B. S. Sonde.
2. Operational Amplifiers by G. B. Clayton (5th edition) Newnes.
3. Operational Amplifiers Applications by G. B. Clayton.
4. Integrated Electronics by Millman and Hallkias.
5. Pulse Digital & Switching Waveforms by Millman and Taub.
6. Microelectronics by Millman&Gabel.
7. Fundamentals of electronics by J. D. Ryder.
8. Electronic Communication System by Kennedy.

Theory Paper SSA-304: Elective - 2B. Radio Astronomy

Unit-I: Radio Astronomy Fundamentals

Radio window of electromagnetic spectrum, nature of radio signal, Brightness, brightness temperature and antenna temperatures, sensitivity, brightness distribution, discrete radio sources of thermal and non thermal radiation, radiative transfer, flux density, Nyquist theorem and the noise temperature.

Unit-II: Theories of Generation of Radio Waves

Bremstrahlung, gyro-synchrotron radiation, Plasma radiation, propagation of radio waves in ionized gases, Wave Polarization, polarization ellipse and Poincare sphere, Stoke's parameters, Faraday rotation.

Unit-III: Solar Radio astronomy

Quiet Sun radiation, slowly varying component, Solar radio bursts on centimetre and decimetre meter wavelength, Solar radio bursts on meter wavelength (type I, II, III, IV & V) bursts and their association with flares.

Unit-IV: Galactic Radio Astronomy

Galactic disk radio component, HII regions and supernovae remnants, 21-cm hydrogen line, CO and OH line radiations. Spiral structure of the galaxy, pulsars and energy losses.

Unit-V: Extragalactic Radio Astronomy

Cosmic microwave background radiation (CMBR), radio galaxies, radio quiet and radio loud galaxies, spectral classifications, active galactic nuclei, Type I and II classifications, broad line and narrow line regions, QSO's, The unified model of Quasars

REFERENCES

1. J. D. Kraus: Radio Astronomy.
2. Mukul R. Kundu: Solar Radio Astronomy
3. Bernard F. Burke and F. Graham-Smith: An introduction to Radio Astronomy (3rd edition)

4. Alan Sandage and others: Galaxies and the Universe
5. Thomas L. Wilson, Kristen Rohlfs, Susanne Huttemeister: Tools of Radio Astronomy (5th Edition)
6. Jeff Lashley: The Radio Sky and How to Observe It.

Practical Paper SSA -351: Electronics

1. Regulated Power Supply
2. RC Coupled Amplifier
3. Experiments on OPAMP
4. Experiments on Multi-vibrators
5. Experiments on Oscillators

Practical Paper SSA -352: Spectroscopy

1. Knowing and Understanding a spectra
2. Classification, measurement of equivalent width and distance of stellar spectra using virtual observatory
3. Plotting and measuring spectra.
4. Determining orbital elements of spectroscopic binary from radial velocity curve.

Practical Paper AS-353: Seminar

REFERENCES

1. An Atlas of Stellar spectra by Morgan, Keenan and Kellman.
2. Clea Software Manual, Department of Physics, Gettysburg College, Gettysburg.
3. C. R. Kitchin: Astrophysical Techniques (4th edition).

Theory Paper SSA -401: Space Physics

Unit-I: Introduction to Earth's Atmosphere

Origin and Composition of the atmosphere, Different Atmospheric Layers: Temperature, Pressure, and Density Distribution with height, Hydrostatic Equation, Greenhouse Gases and Effective temperature of the Earth, Atmospheric Aerosols: Concentration and Size distribution, Production and Removal mechanism. Comparative study of atmospheric properties of Venus and Mars

Unit-II: The Earth's Middle and Upper Atmosphere

Composition and structure of Stratosphere and Mesosphere, Stratospheric ozone chemistry, Formation and structure of the ionosphere, studies of ionosphere by ground and space based techniques, D, E and F region irregularities, Ionization and energy exchange processes. Exosphere.

Unit-III: Solar Radiation

Spectral distribution of solar radiation, Spectrum of Radiation, Radiation law's, Absorption and scattering of solar radiation, Estimation of Solar Irradiance at the upper Atmosphere, Rayleigh and Mie scattering

Unit-IV: Solar Wind

Solar wind: Fast and slow solar wind, Observations of solar wind, Interplanetary magnetic field, Solar wind and its interaction with planetary atmosphere, Variation of solar wind with

solar activity, solar wind at heliopause.

Unit-V: Solar Terrestrial Relationship

Short and long term variability of solar constant, planetary magnetosphere, Structure of the bow shocks, Geomagnetic storm, sub-storms, Magnetic reconnection processes, radiation belts, Aurorae.

REFERENCES

1. J. A. Ratcliffe: An Introduction to the Ionosphere and Magnetosphere.
2. Kaula. W.M: An Introduction to Planetary Physics.
3. Harold Zirin: Astrophysics of the Sun.
4. A. Chandrasekar: Basics of Atmospheric Science
5. The Earth's Ionosphere Plasma Physics and Electrodynamics by Michael C. Kelley
6. V. Bedmtay and Kleczek: Basic Mechanism of Solar Activity
7. Michael D. Papagiannis: Space Physics and Space Astronomy

Theory Paper SSA -402: Binary Stars

Unit -I: Visual and spectroscopic binaries

Introduction to binary stars. Binary types and their classification. Method of observing visual binaries and their orbital elements. Single and double-lined spectroscopic binaries. Method of observing Spectroscopic binaries, Geometry of a spectroscopic binary. Radial velocity curve and its important features. Importance of binary stars in determining the stellar masses.

Unit -II: Eclipsing Binaries

Definition of eclipsing binaries. Method of observing eclipsing binaries. Types of light curves of eclipsing binaries. Classification of eclipsing binaries. Outline of various methods of solving eclipsing binary light curves. W UMa - Definition, properties, period changes, models and evolution. Information obtained from the studies of eclipsing binary light curves.

Unit-III: Other Close Binaries

Astrometric binaries, Algols- Definition, paradox, properties, period changes, models and evolution. RS CVn's- Definition, properties, period changes, models and evolution. White Dwarf binaries - Definition, classifications viz. polars, Intermediate polars and cataclysmic variables.

Unit-IV: X-ray binaries

Accretion disk, Shakura-Sunyeu disk, its spectrum. X-ray binaries - Definition, LMXB and HMXB. Neutron star X-ray binaries. Classification viz. atoll and Z sources. Black hole X-ray binaries, classification based on X-ray spectrum.

Unit-V: Exoplanets Detection techniques

Introduction to exoplanets, Exoplanet History and Planetary Orbits. Detecting planets via astrometry, direct imaging, microlensing, radial velocities, transits, Exoplanet Atmospheres and Interiors.

REFERENCES

1. L. Binnendijk: Properties of Double Stars.
2. F. B. Wood and J. Sahade: Interacting Binary Stars.

3. Z. Kopal: Close Binary Systems.
4. Pringle and Wade: Interacting Binary Stars.
5. K. D. Abhyankar: Astrophysics-Stars and Galaxies (Chap.6) Tata McGraw Hill.
6. The Exoplanet Handbook, 2nd Ed., by Michael Perryman , 2018 (CUP).
7. Transiting Exoplanets, by Carole Haswell (2010; Cambridge University Press)
8. Z. Kopal: Dynamics of Close Binary Systems.
9. Bowers and Deeming: Astrophysics. Vol.1 & 2.
10. Accretion power in Astrophysics: Frank, King and Raine, (CUP).

Theory Paper SSA -403: Elective – 1A. The Milky Way Galaxy & Interstellar Matter

Unit-I: The Milky Way Galaxy

The structure, size using optical and radio observations. mass of the milky way Galaxy and their determinations. Stellar populations in the Milky Way. Distribution of Gas in the Milky Way. Interstellar reddening law. 21-cm line observations. Interstellar magnetic fields in the Milky Way.

Unit-II: Stellar Motions

Standards of Rest – the Fundamental Standard of Rest and the Local Standard of Rest. Solar motion and its determination. Motion of stars in spiral galaxies. Oort's theory of galactic rotation. Determination of Oort's constants. Peculiar velocities.

Unit-III: Spiral Wave Kinematics

Motion of stars near the centre of the Milky Way. Inference of the presence of super massive black hole at the centre. Rotational curve and its interpretation. Dark Matter. Gravitational lensing

Unit-IV: Structure & contents of the Milky Way Galaxy

Star forming regions in the Milky Way. Distribution of X-ray and Gamma ray sources in the Milky Way. Emission mechanisms associated with high energy emissions. Importance of multi-wavelength studies of the Milky Way.

Unit-V: Models for Milky ways

Mathematical models of the Milky way: Uniform sphere model, Isothermal sphere, Plummer's and Hernquist model, Jaffe's model, velocities of bodies, Disk models viz. Exponential and Kepler's disk model

REFERENCES

1. James Binney: Galactic Astronomy: Structure and Kinematics of Galaxies
2. Elmegreen: Galaxies & Galactic Structure. Prentice Hall 1998.
3. Sparke and Gallagher: Galaxies in the Universe.
4. Frank Shu: The Physical Universe. A. Unsold: The New Cosmos (3rd Edition). Springer-Verlag 1983.
5. Mihalas and J. Binney: Galactic Astronomy. W. H. Freeman 1981.
6. K. D. Abhyankar: Astrophysics - Stars and Galaxies. Tata McGraw Hill Publication.
7. L. Spitzer: Physical Processes in the Interstellar Medium. John Wiley 1978.
8. M. Sandage and J. Kristian: (Ed.) Galaxies and the Universe, Cambridge Univ. Press.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. Baidyanath Basu: Introduction to Astrophysics.

Theory Paper SSA -403: Elective – 1B. Galaxies and Universe

Unit-I: Fundamental concept

Introduction - What are galaxies? The Universe of galaxies and their discovery, properties of Milky way, Various catalogues and data sources. Classification of galaxies – Hubble's Morphological Classification, de Vaucouleur Classification, The Yerkes (or Morgan) scheme, DDO system. Masses and sizes of galaxies and the techniques of determining them. Methods of determining extra-galactic distances. Integrated galaxy light, Reddening, K correction.

Unit-II: Profiles of Galaxies

Differential galaxy light, Azimuthal profiles of Ellipticals and Spirals, Isophotal twists in Ellipticals and Spirals. Radial profiles for Spirals and Barred Spirals. Distribution of gas in galaxies. Radiation from neutral atomic, molecular and ionised gas. Total gas mass in a galaxy. Radial gas density profiles.

Unit-III: Dynamical aspects of galaxies

Stellar motion in elliptical and spiral galaxies. Doppler-shift motions in spiral disks, rotational curves, Tully-Fisher relation. Mass distribution in disk galaxies. Early-type galaxy rotations and velocity dispersions. The fundamental plane of Elliptical galaxies. Masses of early-type galaxies.

Unit-IV: Star formation in galaxies

Star formation rates. Complexes and propagating star formation. Starburst galaxies, Star formation in Interacting galaxies. Active Galaxies. Seyferts, Radio galaxies and Quasars. The unified model of Quasars, Importance of multi-wavelength studies of galaxies.

Unit-V: Cosmology

Expansion of the universe. Interpretation of the red-shift. CMBR. Fundamentals of cosmology, Friedmann equations and solutions - the Big Bang & the Steady State models.

REFERENCES

1. Elmegreen: Galaxies & Galactic Structure. Prentice Hall 1998.
2. Sparke and Gallagher: Galaxies in the Universe.
3. Frank Shu: The Physical Universe.
4. A. Unsold: The New Cosmos (3rd Edition). Springer-Verlag 1983.
5. Mihalas and J. Binney: Galactic Astronomy. W. H. Freeman 1981.
6. K. D. Abhyankar: Astrophysics - Stars and Galaxies. Tata McGraw Hill Publication.
7. L. Spitzer: Physical Processes in the Interstellar Medium. John Wiley 1978.
8. M. Sandage and J. Kristian: (Ed.) Galaxies and the Universe. University of Chicago Press.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. Baidyanath Basu: Introduction to Astrophysics. Prentice Hall of India, 2004.
11. Jayant Narlikar: Introduction to Cosmology. Jones & Bartlett Publishers, Inc, 1998.

Practical Paper SSA -451: Photometry

1. Determination of atmospheric extinction -method-I.
2. Determination of atmospheric extinction -method-II.

3. Photometric standardization
4. Light curve of variables

Practical Paper SSA -452: Sky Observation

1. Identification and evolution of celestial sphere with naked eye observations.
2. Identification, imaging and study of celestial objects using 12-inch Meade telescope

Practical Paper SSA -452: Project Work

REFERENCES

1. C. R. Kitchin: Astrophysical Techniques (4th edition).
2. W. A. Hiltner (Ed): Astronomical Techniques.
3. Steve B. Howell: handbook of CCD Astronomy (2nd edition).

Note:-

The syllabus of Osmania University for M.Sc. in Astronomy has been adopted with some changes for M.Sc. in Space Science and Astronomy for Aryabhata knowledge University, Patna. Basic Changes are of the following nature:

- (i) Some new topics are added.
- (ii) Some new contents in a topic are added.
- (iii) Credits has been increased from 82 to 98.
- (iv) A new topic of general nature with title National Security and Strategy of 3 credits has been added as an additional paper in semester -2 of SSA.
- (v) Timing of practical examinations will be 4 hours in general but in some cases it may be different following the nature of examination. It may be notified with the notification of practical examination.
- (vi) One credit means 10 hours learning time.
- (vii) Continuous Internal Assessment will be of 30 marks.
- (viii) The Semester examination will be of 70 marks.

Fee Structure of M.Sc. Course in Space Science and Astronomy

Sl. No.	Particular	1 st Sem.	2 nd Sem.	3 rd Sem.	4 th Sem.
1.	Admission Fee	5000.00	-	-	-
2.	Development Fee	10000.00	-	-	-
3.	Tuition Fee	12000.00	12000.00	12000.00	12000.00
4.	Student Activity Fee	5000.00	5000.00	5000.00	5000.00
5.	Caution Money (Refundable)	2000.00	-	-	-
6.	Registration Fee	2000.00	-	-	-
7.	Examination Fee	2000.00	2000.00	2000.00	2000.00
8.	Thesis Evaluation Fee	-	-	-	5000.00
9.	Student Welfare Fund	1000.00	-	1000.00	-
Total		39000.00	19000.00	20000.00	24000.00

G. Total- 102000/-

4. Job Prospects in the field of space Science and Astronomy:-

4.1. Job prospect in the field of Space Science and Astronomy:

The field of space science and astronomy offers diverse job prospects, ranging from research and academia to the space industry and data science. With the increasing focus on space exploration and technology, the demand for professionals in these fields is expected to grow 7% from 2023 to 2033 which is faster than the average for all occupations. Specifically, there are about 1600 projected openings for physicists and astronomers each year on average. This growth is driven by increasing investment in space exploration and related technologies, as well as a growing need for expertise in these fields.

The astronomer job market is expected to grow 8.3% between 2022 to 2032.

- (i) Astrophysicist: to study physical properties and processes of celestial objects.
- (ii) Astronomer: to study the universe, planets and stars using telescopes and other instruments.
- (iii) Aerospace Engineer: to use, develop and test aircraft, spacecrafts and related systems.
- (iv) Planetary Scientists: to study planets, moons and other bodies in our solar system.
- (v) Education and outreach : Teachers and STEM (Science, Technology, Engineering and Mathematics) educators play a crucial role in inspiring the next generation of Scientists and engineers by promoting space science and astronomy education.
- (vi) Industry and Private sector: The growing space industry offers opportunities in areas like satellite development, space tourism, and space based technology. Many companies activity are hiring professionals with skill in space science, engineering and data analysis.
- (vii) Government Agencies: Government agencies like NASA and ISRO provide opportunity for research, engineering and administration related space exploration and scientific discoveries.
- (viii) Other Related Fields: Careers in fields like meteorology, atmospheric science and geology and can also contribute to space science and exploration.

- (ix) Health issues under zero gravity is a major field of concern.
- (x) Space war techniques are in forefront and is considered as a fourth dimension of modern war.
- (xi) Space tourism is opening huge opportunity of job seekers.
- (xii) Space business has potentiality of large attraction.

5. EXAMINATION & EVALUATION

5.1 MEDIUM OF INSTRUCTION & EXAMINATION

- i The language for the instruction and examination shall be English.
- ii In cases where the programme pertains to any language other than English, the instructions and examinations would be in that language.

5.2 PROCEDURE

- i A student shall be continuously evaluated for academic performance in a course through Continuous Internal Assessment (tutorials, practical work, assignment (s), term paper, field work, seminar (s), periodical tests etc.) and the End-Semester Examination, as prescribed in the examination scheme of the respective course and duly approved by the authority concerned.
- ii The distribution of weightage for each component of assessment shall be as decided by the BoS.
- iii The Continuous Internal Assessment (CIA) and End-Semester Examination shall be conducted by the teacher concerned under the overall supervision of the Head of the Centre and Dean of the School. The Head of the Centre shall report the award list of CIA and End Semester Examination in respect of all courses taken by different students to the Controller of Examinations through the Dean of the School within seven days of the completion of examination.
- iv In case of a student could not appear in any of the components of the CIA due to medical reasons or under exceptional circumstances, a separate examination in that component may be arranged by the Head

of the Centre (supported by documentary evidence) before the End Semester Examination.

- v The End Semester Practical Examination (wherever applicable) shall ordinarily be held before the theory examinations.
- vi To be eligible to appear in the End-Semester Examination of a course, the student shall have to clear the CIA of that particular course with a minimum of 50% marks. If the student fails to secure 50% marks in CIA for that course, the student shall have to repeat the course.
- vii A student shall be awarded a letter grade in each course she/he shall be registered for, indicating his/her overall performance in that course. These grades and corresponding grade points (on a 10-point scale) is given below.

Grading Scheme:

Description	Letter grade	Grade points per Credit	Range of marks (%)
Excellent	A+	10	≥ 90
Very Good	A	9	≥ 80 & < 90
Good	B	8	≥ 70 & < 80
Fair	C	7	≥ 60 & < 70
Average	P	6	≥ 50 & < 60
Fail	F		< 50 ; for theory component < 50 ; for laboratory component