Course: M.Sc (Physics)

Semester	4
Paper Number	17 (MPHC4403)
Paper Title	Galaxies and Particle Astrophysics
No. of Credits	6
Course description/objective	**Group A:** The aim is also to enable a student to visualize the geometric structure of space-time represented by a black hole solution of Einstein's equation and the trajectories of photons in such space-times. It also aims to teach the students that accretion is one of the most important energy generation mechanisms. This course aims to educate the students about some major components of the universe like the galaxies and interstellar medium, about their classification and the physical principles involved in their formation and evolution. **Group B:** In this part of the course, the students are taught canonical quantization of the real scalar field, the complex scalar field, the electromagnetic field and the Dirac field. They are also introduced to the concept of spontaneous symmetry breaking and the generation of mass by the Higgs' mechanism The Objective of this course is to learn about the history and evolution of the idea of using cosmic rays as astrophysical probes. To this ends the course takes the students through possible scenarios of cosmic ray generation, acceleration, interaction with terrestrial atmosphere and their detection methods. It also provides an introduction to candidate dark matter objects and experiment along with a brief description of gravitational wave phenomena.
Course Outcome	**Group A** **Compact Objects:** CO1: To understand the basic mechanisms involved in the formation of compact objects like neutron stars, black holes, x-ray sources, pulsars, etc. CO2: To gather an in-depth knowledge about the mechanism of gravitational collapse leading to the formation of black holes, and the significance of trapped surfaces and horizons. CO3: To apply this knowledge to understand the coordinate transformations used to handle a singularity and the corresponding change in the nature of light cones, so as to understand the global properties and causal structure of space-times. CO4: To learn about the structure and evolution of white dwarfs and neutron stars so as to analyze the conditions of stability of white dwarfs and study the parameters associated with neutron star binaries. **Interstellar Medium and Galaxies:** CO1: Understand the birth and collapse of stars in the interstellar medium CO2: Appreciate that the physical laws that can be applied to the ISM can be extended to intergalactic medium and galaxies CO3: Learn and appreciate galaxies and their evolution as a major component of the structures of the universe. **Group B** **Standard Model:**

	CO1: After completing this course, the students should be able to quantize the scalar fields, the electromagnetic field and the Dirac field, canonically. CO2: They should also have obtained a basic understanding of spontaneous symmetry breaking. **Astroparticle Physics:** CO1: Develop skill in relativistic dynamics using examples from the physics of interaction of cosmic rays with particles in IGM / Terrestrial atmosphere. CO2: Learn about the operating principles of Cosmic ray detectors and how they extend and contribute to multi-messenger astronomy CO3: Understand the implications of massive neutrino states CO4: Learn about particle candidates of Dark matter

Syllabus	**Group A:** **Compact Objects, Interstellar Medium & Galaxies [36 Lectures]** **Compact Objects [24 lectures]** Black holes and compact objects. White Dwarfs and Neutron Stars, Compact X-Ray Sources, Radio Pulsars, Supermassive and other Black Holes, Gamma-Ray Bursters. [4 lectures] Collapse of stars and formation of black holes; singularities and trapped surfaces, event horizon; Schwarzschild Black Hole, Tortoise Coordinates and Null Cones, The Kruskal Extension, Penrose Diagram – the Conformal Structure of Infinity. Kerr Black Hole; Boyer–Lindquist Coordinates, ergosphere; Weyl–Papapetrou form of the Kerr Metric, uniqueness of the Kerr solution. Dark Energy stars. Black hole accretion and accretion disk properties. [10 lectures] White Dwarfs and Classification. Equation of State below the Neutron Drip Density, Structure of White Dwarfs and the Chandrasekhar Mass, Polytropic Approximation, Relativistic Instability of White Dwarf Stars, Necessary Condition for Stability, Total Energy in the Post-Newtonian Limit, GR White Dwarf Instability. [5 lectures] Structure of a Neutron Star, Equations of State beyond Neutron Drip, From Neutron Drip to Saturation, Nuclear EoS for Dense Neutron Matter. Structure of Massive Neutron Stars. Periastron Shift, Shapiro Time Delay in a Binary System. [5 lectures] **Interstellar Medium and Galaxies [12 lectures]** Interstellar medium and star formation: Interstellar dust and gas, formation of proto-stars, pre-main sequence evolution, initial mass function [5 lectures] Galaxies: The Milky Way, Distribution of stars, Morphology, Kinematics, Neutral hydrogen(HI 21cm line)---Dark matter, Galactic Center, Normal galaxies: morphological classification, physical characteristics and kinematics, Intergalactic Medium.

	[7 lectures] **<u>Group B:</u>** **Standard Model and Astroparticle Physics [36 Lectures]** **Standard Model [24 Lectures]** Standard Model of Particle Interactions, Classical Field theory: Noether's Theorem and applications. [4 lectures] Quantum Field Theory: Quantization of the Klein-Gordon, Dirac and Electromagnetic Field. [10 lectures] Gauge theories of electromagnetic and weak interactions. [6 lectures] Spontaneous Symmetry breaking and elementary idea about the Higgs' mechanism. [4 lectures] **Astroparticle Physics [12 Lectures]** Astroparticle physics in perspective: Relationship to High Energy Physics, Astrophysics and Cosmology. Elementary particle processes in galactic, intergalactic and atmospheric production and transmissions, Physics of particle and radiation detection. [4 lectures] Acceleration mechanisms in sunspots, supernovae shocks and accreting binaries. [4 lectures] Primary and secondary cosmic rays: Charged and uncharged components: neutrino, gamma, x-ray and gravitational wave astronomy. Secondary cosmic rays: Atmospheric propagation, cosmic rays at the sea level and underground, Extensive air showers (elementary theory). [4 lectures]
References	**<u>Group A:</u>** **Compact Objects** 1.M. Camenzind, Compact Objects in Astrophysics 2. Stuart L. Shapiro and Saul A. Teukolsky, Black Holes, White Dwarfs, and Neutron Stars – The Physics of Compact Objects 3. Sean Carroll, Spacetime and Geometry 4. J. B. Hartle, Gravity – An Introduction to Einstein's General Relativity **Interstellar Medium and Galaxies** 1. An introduction to the theory of stellar structure and evolution by Dina Prialnik

	(Cambridge University Press) 2. Physics of the Interstellar and Intergalactic Medium by B. T. Draine (Princeton Series in Astrophysics) 3. The Physics of the Interstellar Medium, J. E. Dyson and D. A. Williams (CRC Press) 3. Galaxies in the Universe by Sparke and Gallagher, Cambridge University Press (2007) 4. An Introduction to Modern Astrophysics by B. W. Carrol and D. A. Ostlie (Pearson, 2006) 5. Galactic Astronomy by J. Binney & M. Merrifield (Princeton Series in Astrophysics) 6. Galactic Dynamics by J. Binney & S. Tremaine (Princeton Series in Astrophysics) **Group B:** **Standard Model** 1.A first course in quantum field theory by A. Lahiri & P. B. Pal 2. Quarks and Leptons: an introductory course in modern particle physics by F. Halzen & A. D. Martin. **Astroparticle Physics** 1.Vanessa Cirkel-Bartelt - History of Astroparticle Physics 2. Claus Grupen : Astroparticle Physics 3. Donald Perkins: Particle Astrophysics 4. Claus Grupen : Particle Detectors
Evaluation	Total: 100 CIA: 10 (Group A) + 10 (Group B) End Semester Examination: 40 (Group A) + 40 (Group B)