SECOND SEMESTER 2020-21
COURSE HANDOUT

Date: 15.01.2021

In addition to part I (General Handout for all courses appended to the Time table) this portion gives further specific details regarding the course.

Course No : PHY F215

Course Title : Introduction to Astronomy & Astrophysics
Instructor-in-Charge : **Kaushar Vaidya**
Instructor(s) : **Kaushar Vaidya**
Tutorial/Practical Instructors: NA

1. Course Description:

This course is an introductory course in Astronomy and Astrophysics. The course covers all the topics in the field of stellar astrophysics, and selected topics in the Galactic Astronomy.

2. Scope and Objective of the Course:

This course will mainly introduce a student to the field of Stellar Astrophysics. The course will begin with a quick review of the history of Astronomy, followed by a discussion of basic concepts of Observational Astronomy, and familiarize a student with various tools of Astronomy such as telescopes, detectors, and techniques involved in multi-wavelength astronomy.

The course shall deal with topics in Stellar Astrophysics in four broad categories: Stellar atmospheres (outer layers of stars), Stellar interiors and Stellar Structure, Stellar Evolution, and End States of Stars.

Stellar atmospheres are the only directly observable layers of stars. We can study stellar atmospheres by obtaining spectra of stars. In this course, we will learn how to interpret stellar spectra using the laws of Physics. We will learn how to derive abundances of elements in the stellar atmospheres from stellar spectra as well as how to obtain different estimates of the "surface" temperatures of stars.

We cannot observe interiors of stars directly. We build models of stars using the basic observations of stars and check our models against some of the unique observations possible only for our closest star (the Sun). In stellar structure and interiors, we will study how stars produce their energy, how they maintain their equilibrium, how they transport energy in their interiors as well as to the outside. We will make use of the most detailed observations of our closest star, the Sun, to check if our models are correct (i.e. the energy production by nuclear fusion, the radiative/convective structure of star, the temperature profile etc.)

If we had only one star at our disposal to study and learn about the working of stars, we certainly would not be able to make a headway. The theory of stellar evolution, which is one of the most successful theories of Astrophysics, is a study of stellar systems, such as star clusters to know different stages in stars' evolution. As stars evolve, they undergo changes in their cores as a result of nuclear fusion. These changes demand that star constantly makes adjustments to remain in mechanical and thermal equilibrium, as well as maintain its output. Eventually stars exhaust their core Hydrogen which marks the end of stars main-sequence life. Stars consume their nuclear fuel at different rates and have their main-sequence lifetimes as varied as a few million years (the most massive stars) to tens of billions of years (the lowest mass stars). Star clusters provide us samples of stars that are similar to one another in terms of their chemical abundances, kinematics, and distance from the Sun. In stellar evolution, by studying these collective, coeval, samples of stars, we will learn about the various stages that stars would go through post main-sequence, and see the observational correspondence for each of these phases.

Most stars would end as white-dwarfs, some stars would end as neutron stars, and a small fraction of stars would end up as black holes. In neither of these phases, would star produce any nuclear energy. Moreover, a strange form of

pressure would support stars in these end phases against gravity. We will learn about the strange physical properties of stars when they are in their end states. Apart from studying the physics of these objects, we will also learn about how these objects are observed.

3. Text Books: "An Introduction to Modern Astrophysics" by Bradley Carroll & Dale Ostlie, Second Edition, Pearson (Addison Wesley), 2007

4. Reference Books: "The Physical Universe" by Frank Shu, University Science Books, 1982

"Astrophysics For Physicists" by Arnab Rai Choudhuri, Cambridge University Press, 2010

5. Course Plan:

Module	Lecture Number	Topics to be covered	Learning Outcome	Reference
1. History	1 (1)	History of Astronomy	• The Big Questions of Ancient Astronomy	Chapter 1
2. Concepts in Astronomy	2-3 (2)	Celestial Mechanics; Distances in Astronomy; Magnitude Scale; Color-index	• How to label a celestial object, a star or a galaxy by its coordinates • Different coordinate systems and their pros and cons • Parallax method of determining distances to the nearest stars • Magnitude scale to relate the apparent brightness of stars • Color-index and its use as a temperature indicator	Ch.1 (S 1.3); Ch. 3 (S 3.1, 3.2, 3.6)
3. Telescopes	4-5 (2)	Basic Optics; Optical Telescopes; Radio Telescopes; Infrared, Ultraviolet, X-ray, and Gamma-Ray Astronomy	• Important parameters in designs of telescopes • Different kinds of detectors • Multi-wavelength Astronomy and their use	Chapter 6
4. Stellar Spectra	6-9 (4)	Maxwell-Boltzmann distribution, Bolzmann equation, Saha equation, Formation of Spectral Lines,H-R Diagram, Luminosity	• Using results from Statistical Mechanics branch of Physics, learning how to determine average velocity for a large number of particles • Determining probabilities of particles being in different excitation levels in an atom	Chapter 8

		Class	using Boltzmann equation • Determining probabilities of particles being in different ionization levels using Saha equation • Spectral line formation • Different kinds of spectra, classification of stars into nine classes • The most important diagram of stellar astrophysics: H-R diagram	
5. Stellar Atmospheres	10-13 (4)	Description of Radiation Field, Stellar Opacity, Radiative Transfer, Transfer Equation	• Definitions of radiation field: specific intensity, flux, energy density • How to write an expression for loss in intensity due to absorption processes • How to write an expression for gain in intensity due to emission processes • Transfer Equation and special solutions (Interpretation of Kirchoff's laws) • Different contributors to absorption/emission: bound-bound, bound-free, free-free transitions, electron scattering • Learning concepts such as Local Thermodynamic Equilibrium (Mean Free Path, Temperature Scale Height)	Chapter 9
6. Interiors of Stars	14-21 (8)	Hydrostatic Equilibrium, Pressure Equation of State, Stellar Energy Sources, Energy Transport, Main Sequence	• How pressure-gradient (gas and radiative) balances the weight and ensures stability of stars • Energy sources of stars: gravitational, chemical, nuclear • p-p chain and CNO chain of Hydrogen fusion • Binding Energy per nucleon • Energy Transfer: Radiation and convection • Stellar Models: Stellar Structure Equations,	Chapter 10

			Constitutive relations, boundary conditions	
7. Sun	22-24(3)	Solar Interiors, Solar Neutrino Problem, Solar Atmospheres	• Evolution of Sun on the main-sequence • Solar neutrino problem, its solution, and implications • Solar atmospheres: Photosphere, Chromosphere, Corona • Solar Magnetic Cycle, sunspots	Chapter 11
8. Stellar Evolution	25-27 (3)	Stages of Stellar Evolution, Stellar Clusters	• Subgiant branch, Red giant branch, Asymptotic giant branch, Horizontal branch, Planetary nebulae • Stellar Clusters, Open clusters, Globuler clusters	Chapter 13
9. Stellar Evolution	28-30 (3)	Evolution of massive stars, Supernovae, Gamma-Ray bursts	• Two kinds of Supernovae • Gamma-Ray bursts	Chapter 15
10. Degenerate Remnant Stars	31-35 (4)	White Dwarfs, Chandrasekhar Limit, Neutron Stars, Pulsars	• The case of Sirius-B • White dwarfs • Fermi Energy • The physics of degenerate matter • The Chandrasekhar limit • Cooling of White dwarfs • Neutron Stars • Pulsars	Chapter 16

6. Evaluation Scheme:

Component	Duration	Weightage (%)	Date & Time	Nature of component (Close Book/ Open Book)
Mid-Semester Test	90 Min.	30	<TEST_1>	Closed/Open
Comprehensive Examination	3 h	40	<TEST_C>	Closed/Open
Weekly Quiz	10 Min.	30	Throughout	Closed

7. Chamber Consultation Hour: TBA

8. Notices: On Nalanda.

9. Make-up Policy: Very Strict. Only to the most genuine cases as judged by the IC.

10. Note (if any):

Instructor-in-charge
Course No.