ASTR 702 – Stellar Structure and Evolution – Fall 2020

Instructor: Dr. Maura McLaughlin

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Office hours: By appointment at calendly.com/mamclaughlin

Class times: T/R 1000-1115 on Zoom

Aim: The goal of this course is to give you a good working understanding of stellar properties, how stars generate energy, and how stars are born and die. We will become familiar with the properties (e.g. temperatures, ages, chemical compositions) of stars and the different states of matter that make up stars. We will understand hydrostatic equilibrium, nuclear fusion and energy transport. We will follow the lifecycles of different types of stars and understand the properties of the different end-points.

We will concentrate on understanding the physics of stars using simple calculations covering a very large range of physical principles. Many of our calculations will be order-of-magnitude and back-of-the-envelope as we will aim to simply understand principles without getting bogged down in minutiae. Secondary goals of the course are to understand what the current important problems in the field are, and to be able to interpret and communicate scientific results that are related to the topics we will cover in the course.

While this course is designed to prepare students for careers as astrophysicists, the physics we will cover has a very broad range of applications, and the approach to problems should help in tackling difficult problems in many areas of physics.

Prerequisites: If you have an undergraduate degree in Physics or Astronomy and have had undergraduate classes in electromagnetism, thermodynamics, quantum mechanisms, and modern physics you should be prepared for this course.

Text: The required textbook for this course is

Stellar Interiors by Hansen, Kawaler and Trimble

The other three main textbooks that I will use are

An Introduction to the Theory of Stellar Structure and Evolution by Prialnik
Principles and Stellar Evolution and Nucleosynthesis by Clayton Black
Holes, White Dwarfs and Neutron Stars by Shapiro and Teukolsky

The first is an advanced undergraduate book and is excellent for a big-picture view of the topics covered. The second is a graduate text which is essential for a detailed look at stellar nucleosynthesis. The last one covers many things about compact objects which are glossed over in the Hansen text.

Other texts that may be useful are
Introductory Astronomy and Astrophysics by Zeilik and Gregory
Introduction to Stellar Structure by Chandrasekhar
Radiative Processes in Astrophysics by Rybicki and Lightman

All of the above mentioned texts are on reserve at the library.

Homework and Exams: Homework will be assigned every one or two weeks, to be due one week later. Homework should submitted electronically to my email address by class-time on the due date. It can be hand-written and scanned or typed up. I encourage you to talk with each other about the homework, but the actual solutions must be completely your own. There will be a midterm and a final exam, carried out over Zoom. These obviously must be done completely on your own!

Homework will be graded mostly on conceptual understanding, and a smaller part on math. If your math for a particular problem doesn't work out and you find, for instance, that the mass of neutron star is 1 g, please tell me in your homework solutions that you know your answer doesn't make sense!

Late homework will not be accepted, but I will drop your lowest homework.

Attendance: If at all possible, please have your camera on for Zoom lectures. There will be discussions and in-class questions that count towards the 10% participation part of the grading scale. You are allowed three absences over the course of the semester (barring extraordinary circumstances), and for each additional absence you will lose one percentage point. If you are going to be absent from class, please let me know at least one hour before class starts.

Grading: Your grade will be comprised of the following parts:

60% Homework
10% Class project
20% Online quizzes
10% Participation

You will get at least the following letter grades for the following percentage grades:

90-100% A
80-90% B
70-80% C
60-70% D
< 60% F

Syllabus:

1) What is a star? What are our astronomical observables? Overview of the HR diagram and the properties of stars. What simplifying assumptions can we make? (1 week)

2) Basic underlying principles such as hydrostatic equlibrium, perfect gas equation of state, virial theorum, stability of self-gravitating spheres. (1 week)

2) Characteristic timescales of evolution, maximum mass of planets and minimum mass for stellar ignition, maximum stellar mass, dimensional analysis and homology relations. (1 week)

3) Energy generation, nuclear reactions, tunneling, p-p chain, CNO cycle, neutrinos. (2 weeks)

4) Basic physical processes of the gas and radiation inside stars, chemical compositions, equations of state, radiation pressure, degeneracy pressure, Saha equation. (1 week)

5) Heat transfer through radiation, conduction and convection, blackbody radition, opacity, Rosseland mean. (2 weeks)

6) Equations of stellar structure, polytropes, Chandrasekhar mass, Eddington luminosity, boundary condidtions, Lane-Emden equation. (2 weeks)

7) Pre-main sequence evolution, Hayashi track, observations and theories. (1 week)

8) End-points of low-mass, intermediate mass and high-mass stars. (1 week)

9) General relativity, black holes and neutron stars. (1 week)

10) Astroseismology and pulsations (1 week)

Social Justice Statement: The West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion.

If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with the Office of Accessibility Services(304-293-6700). For more information on West Virginia University's Diversity, Equity, and Inclusion initiatives, please see http://diversity.wvu.edu/.

I encourage any student who feels intimidated, out of place, or who could use any type of learning assistance, to come and talk to me. **Astrophysics is for everybody!**