Astronomy 310 : STELLAR ASTROPHYSICS

Fall Semester 2008

Basic Information

- **Instructor:** Professor Rich Townsend
- **Contact:**
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  - Mailbox: 5$^{\text{th}}$ floor, Sterling Hall
- **Times/Location:** 09:55 am – 10:45am, Mon, Wed, Fri in Sterling 6515
- **Website:** `http://www.astro.wisc.edu/~townsend/teaching/ASTRON-310/`. This contains the same basic information as this document, plus links to useful resources and (as they become available) notes.
- **Office hours:** Mon, Fri 11:00 am – 12:00am, other times by appointment

Course Overview

Stars are the fundamental building blocks of the Universe. They are the principal source of electromagnetic radiation at many wavelengths, including visible light. By injecting vast amounts of energy and momentum into their surroundings, they act as drivers for the evolution of their host galaxies. Likewise, through their creation of chemical elements heavier than hydrogen and helium, they are ultimately responsible for the existence of life as we know it.

Stellar astrophysics — the study of the appearance, structure, composition, and evolution of stars — is one of the resounding successes of modern physics. It brings together elements from almost every sub-field of physics (from atomic and nuclear physics, through to classical mechanics and relativity), allowing us to understand in surprising detail what goes on deep inside an object that, to us, is a mere pinprick of light in the sky.

This course is aimed at junior or senior majors in Astronomy or a related area, and is divided into three main components:

I. Stellar Observations: how do we quantify the basic parameters of stars (position, distance, brightness, spectrum, etc)?

II. Stellar Atmospheres: how does radiation interact with matter at the surfaces of stars, to produce the spectra that we observe?

III. Stellar Interiors: what processes determine the interior structure, composition and evolution of stars?

Reading

The textbook for the course is *An Introduction to Modern Stellar Astrophysics* (2^{nd} edition), by Carroll & Ostlie (ISBN: 978-08053034830). We will cover most, but not all, of the chapters in the book, and the bi-weekly assignments will be based mainly on the problems given at the end of each chapter. Other books that may be occasionally referenced are as follows:

- *Stellar Structure and Evolution*, by R. Kippenhahn & A. Weigert. A very thorough advanced undergrad/grad-level text that covers most of the details of stellar interiors.
- *Structure and Evolution of the Stars*, by M. Schwarzschild. An introduction to stellar interiors, not quite as in-depth as Kippenhahn & Weigert, but rather more gentle.
- *Stellar Atmospheres*, by D. Mihalas. The standard reference text on stellar atmospheres and radiative transfer.
- *The Internal Constitution of the Stars*, by A. Eddington. One of the easiest-to-read and most insightful books on stellar structure, by the father of modern astrophysics.

All of these books are on reserve in the Astronomy library, apart from the last which can be found in the Physics library.

Software

Apart from various simple cases, calculating stellar interior models requires a computer program. For the purposes of the class, I've created an on-line structure and evolution program, '*EZ Web*', which you can reach at

`http://www.astro.wisc.edu/~townsend/teaching/ezweb/`

(You can also reach *EZ Web* through the course website mentioned above). During the course I'll be giving full instructions on how to use *EZ Web*.

Assignments and Exams

- **Homework:** Assignments will be given out every other Friday, collected on the following Friday, and then returned on the Friday after that (see the schedule below for full details). For the most part, problems will be taken from Carroll & Ostlie, although some additional questions will be posed from time to time. Unless a valid excuse is provided, late assignments will have a small number of points deducted. Students are encouraged to work together on solving homework problems; however, the final *write-up* of the problem must be the student's own work, in their own words.

- **Mid-term Exam:** There will be a 50-minute mid-term exam, to be held during the class on Fri Oct 17. This exam will test the material from the first half of the course (mostly, components I & II described above), and will be open book.
- **Final Exam:** There will be a 2-hour final exam, to be held 07:45 am – 09:45 am on Sat Dec 20. This exam will test all of the material from the course, and will be open book.

Grading

The final grade for the class will depend primarily on weekly assignments (50%); on the mid-term exam (20%); and on the final examination (30%). However, strong and enthusiastic participation in classroom discussions will also be recognized.

Schedule

Date	Topic	Chapters	Homework?
	I. — Stellar Observations		
09/03	Introduction		
09/05	Distance & magnitude	3.1, 3.2	
09/08	Blackbody radiation	3.4–3.6	
09/10	Colors, line spectra	3.6, 5.1	
09/12	Binary systems; visual binaries	7.1, 7.2	1st assigned
09/15	Eclipsing & spectroscopic binaries	7.3	
09/17	The Hertzsprung-Russel diagram	8.2	
09/19	Spectral classification	8.1	1st due
	II. — Stellar Atmospheres		
09/22	Stellar atmospheres	9.1	
09/24	Describing radiation	9.1	
09/26	Radiation & matter	9.2, 9.3	2nd assigned
09/29	Radiative transfer	9.3	
10/01	The Eddington approximation	9.3	
10/03	The grey atmosphere	9.3	2nd due
10/06	Realistic model atmospheres		
10/08	Opacity sources	9.2	
10/10	Spectral features	9.4	3rd assigned
10/12	Profile shapes	9.4	

10/15	Line strengths	9.4	
10/17	**Mid-Term Exam**		3rd due
	III. — Stellar Interiors		
10/20	Mechanical structure	10.1	
10/22	The virial theorem		
10/24	Polytropes		
10/27	Equation of state	10.2	
10/29	Energy conservation; diffusive transport	10.4	
10/31	Mass-luminosity relation; main sequences		4^{th}assigned
11/03	Convective transport	10.4	
11/05	Energy generation	10.3	
11/07	Nuclear fusion networks	10.3	4^{th}due
11/10	Fusion rates	10.3	
11/12	Rotation		
11/14	Stellar model building	10.5	5^{th}assigned
11/17	*EZ-Web*; the main sequence	10.6	
11/19	The Sun	11.1–11.3	
11/21	Massive stars		5^{th}due
11/24	Star formation	12.1,12.2	
11/26	Pre-main-sequence evolution	12.3	6^{th}assigned
11/28	**Thanksgiving Recess**		
12/01	Evolution off the main sequence	13.1,13.2	
12/03	Helium burning & beyond	13.2	
12/05	Stellar death	13.2, 13.3	6^{th}due
12/08	Stellar pulsation	14.1–14.5	
12/10	White dwarfs	15.1–15.5	
12/12	Neutron stars	15.6	
12/20	**Final Exam**		