Astronomy 363: Stellar Astronomy and Astrophysics I

University of Montana
Autumn 2015
MWF 10:10 – 11:00 am
CHCB 231
Course Number 74838

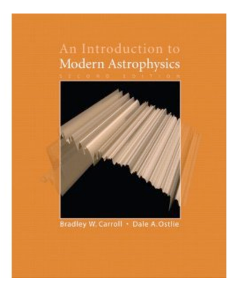
Professor Nate McCrady
e-mail: nate.mccrady@umontana.edu
Office: 122 CH Clapp Building
Office Hours: Tu 2-3 pm, Th 12-1 pm, F 1-2 pm and by appointment
Course website: *see Moodle*

Course Description
The star is the fundamental unit of astronomy. In this course, we will establish a basis for studying the Universe with a physical understanding of the nature of individual stars. We will begin with the observables: stellar properties we can ascertain through direct measurement. From there we will apply physical principles from mechanics, thermodynamics, statistical mechanics, electromagnetism and quantum, atomic and nuclear physics to develop a physical understanding of the nature of stellar interiors. The unifying theme of the course will be to understand the Hertzsprung-Russell diagram via basic principles of physics. The first semester, Astr 363, will focus on the internal structure of an individual main sequence star. In the second semester, Astr 365, we will investigate the time evolution of stars (their birth, death, and remnants) and their atmospheres.

Course Objectives
My goals in Astronomy 363 are to…

1. Familiarize students with basic stellar observations.
2. Develop the fundamental physics that govern stars.
3. Apply physics to determine the internal structure of a solar-type star.

Required Materials
An Introduction to Modern Astrophysics, 2nd Ed.
by Carroll and Ostlie



Available from amazon.com and elsewhere for ~$170.
(This is the same textbook used for Astr 365 and Astr 353, by the way.)

Expectations of the Professor
This upper-division course is intended for physics majors with a concentration in astrophysics. I expect that you will have completed the designated pre- and co-requisite courses: Astronomy 132 or 142 (introductory astronomy), Physics 217 (physics with calculus) and Physics 343 (Modern physics). Integral and differential calculus are essential in this course, and you should have a working understanding of the co-requisite course Math 273 (multivariable

calculus). You should also be comfortable working with logarithms, scientific notation and the Greek alphabet! Time in the classroom is an essential part of this course, and it will be to your benefit to attend lectures. Exams and homework will be based primarily on material presented in class. The readings form the textbook will help you prepare for class meetings. This syllabus includes the assigned readings. *I expect students to read the material in advance of the class on the topic, and to be prepared to discuss the material in class.*

This course is a collaborative effort – please ask questions, offer your ideas and be prepared to participate in the discussion. Written work submitted in this course must be expressed in your own words. I specifically encourage students to work together, but each student must write up her or his own response to problems. This step is essential to your learning – writing up the answer to a question requires you to understand the conclusion of your group, whereas transcription of the work of another does not. When in doubt, please ask me what is acceptable.

And of course, while in class, please turn off your phones and other electronic gadgets. Laptops are acceptable for note-taking, if you so desire.

Pedagogical Philosophy of the Professor

My primary goal in teaching upper-division majors is to help you develop physical intuition and apply principles of fundamental physics learned in introductory coursework. This class in particular is an advanced course in astrophysics, a field of applied physics. As with any applied field, there is a significant amount of vocabulary specific to the discipline. This course will help develop your fluency in the language of astrophysics.

Research in how people learn indicates that the knowledge of an expert in a topic is organized around core concepts. In order to help you develop expertise in stellar astrophysics, I have organized this course around several core concepts. These are listed on the class schedule in this syllabus. Each concept is associated with a number of specific learning goals, a complete list of which I will provide you for use as a study aid. Each learning goal is stated from the student's perspective. If you can achieve these specific goals, you will succeed in this course – and be well on your way towards expertise in stellar astrophysics!

Grading Policy

This course will be graded on the University's traditional letter grade system. Your grade will be based on three midterm exams (12% each), a cumulative final exam (24%), and weekly homework sets (40% total). I have not determined in advance how many As, Bs, etc will be assigned – I'm happy to give every student an A if they demonstrate mastery of the material. Along the way I will provide regular updates regarding your grade in the course.

Midterm exams take place during regular class time on the scheduled days. If you cannot be present, tell me *before* the exam and we can discuss arrangements. For *well-documented* compulsory absences, we will arrange a time for you to take the exam *early*.

Homework must be turned in by 5pm on the due date (generally Fridays). Late homework will be penalized by 10% per weekday. Homework must be legible! If your first attempt is messy, use it as a draft to rewrite a final version for submission. If I can't read it easily, you'll get no credit!

Course Schedule & Reading Assignments

			Readings
		STELLAR OBSERVATIONS	
M	Aug 31	Flux and magnitude	3.2
W	Sep 2	Distance, absolute magnitude & luminosity	3.1
F	Sep 4	Filters, color and photometry	3.6
M	Sept 7	*Labor Day Holiday*	
W	Sept 9	Thermal radiation & the Planck function	3.4, 3.5
F	Sept 11	Stellar spectra	5.1
M	Sept 14	Stefan-Boltzmann law & stellar radii	pp 69-70, pp 144-148
W	Sept 16	Binary stars and stellar mass	Ch. 7
F	Sept 18	Solar measurements & radioactive dating	pp 756-759
M	Sept 21	Hertzsprung-Russell diagram	8.2
W	Sept 23	Mass-luminosity relation and MS lifetimes	p 189
F	Sept 25	**Midterm 1**	
		PHYSICS OF STELLAR STRUCTURE	
M	Sept 28	Gravity & hydrostatic equilibrium	10.1
W	Sept 30	Statistical mechanics and PDFs	
F	Oct 2	Pressure integral and the ideal gas law	10.2
M	Oct 5	Stellar interiors & ionization	pp 213-219
W	Oct 7	Radiation pressure	pp 236-237, p. 295
F	Oct 9	LTE and radiative transfer	pp 251-261
M	Oct 12	Opacity and mean free path	9.2
W	Oct 14	Radiative energy transport	pp 315-316
F	Oct 16	Convective energy transport	pp 316-325
M	Oct 19	Equations of stellar structure	pp 329-332
W	Oct 21	Mass-luminosity relation, revisited	
F	Oct 23	**Midterm 2**	
		STELLAR NUCLEOSYNTHESIS	
M	Oct 26	Four fundamental forces	
W	Oct 28	Nuclear reactions & binding energy	pp 298-302
F	Oct 30	Wave/particle duality & quantum tunneling	pp 127-132
M	Nov 2	Nuclear reaction rates & cross sections	pp 302-308
W	Nov 4	Hydrogen fusion	pp 308-312
F	Nov 6	Helium fusion	pp 312-313

M	Nov 9	Heavies fusion	pp 313-315
W	Nov 11	*Veterans Day Holiday*	
		STELLAR MODELING	
F	Nov 13	Boundary conditions and integrations	pp. 332-334
M	Nov 16	Computer modeling with MESA code	TBA
W	Nov 18	Solar internal structure models	pp 349-356
F	Nov 20	What determines the mass range for stars?	
M	Nov 23	**Midterm 3**	
W	Nov 25	*Thanksgiving Break*	
F	Nov 27	*Thanksgiving Break*	
		THE SUN AS A STAR	
M	Nov 30	Solar elemental abundances and luminosity	
W	Dec 2	Solar neutrinos	pp 356-360
F	Dec 4	Helioseismology	pp 509-512
M	Dec 7	Solar magnetic field and the sunspot cycle	11.3
W	Dec 9	Solar wind & the corona	11.2
F	Dec 11	Review	
W	Dec 16	**Final Exam, 8:00 – 10:00 am**	

Additional Reading

There are several excellent texts on the subject of stellar astrophysics, many of which were used to prepare course material. The texts marked with stars are classics in the field.

The Physics of Stars, 2nd Ed., A.C. Phillips, 1999

Principles of Stellar Evolution and Nucleosynthesis, D. C. Clayton, 1983 ★

Stellar Structure and Evolution, R. Kippenhahn & A. Weigert, 1990

An Introduction to the Study of Stellar Structure, S. Chandrasekhar, 1967 ★