Fall 9-1-2021

ASTR 363.01: Stellar Astronomy and Astrophysics I

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Astronomy 363: Stellar Astronomy and Astrophysics I

University of Montana
Autumn 2021
MWF 10:00 – 10:50 am
CHCB 231
Course Number 74443

Professor Nate McCrady
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Office Hours: by appointment, outdoors or via Zoom

Course Description

The star is the fundamental unit of astronomy. In this course, we will establish a basis for studying the Universe through 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 observed 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

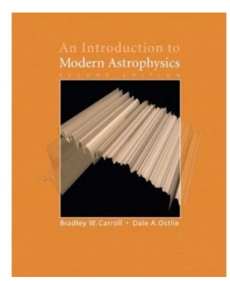
My goals in Astronomy 363 are to…

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 ~$90.
(The same textbook will be used for Astr 365.)



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 from 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.

Public Health and Covid-19

As the semester begins, new cases of Covid-19, predominantly caused by the Delta variant, are increasing in Missoula County and across Montana. **The University of Montana recommends that students, faculty, and staff get the Covid-19 vaccine.** Curry Health Center offers free vaccinations for anyone, on a walk-in basis, during regular business hours. **A mask covering the nose and mouth is required for all individuals while in the classroom or laboratory.** Drinking liquids and eating food is discouraged within the classroom. Please observe physical distancing in the classroom and allow each other space. In this course, classroom windows will be open during class meetings, so please dress accordingly.

If you feel sick and/or are exhibiting Covid-19 symptoms (fever or chills, cough, shortness of breath, fatigue, muscle or body aches, headache, loss of taste or smell, sore throat, congestion or runny nose), do not come to class; contact the Curry Health Center at (406) 243-4330. If you are required to isolate or quarantine, you will receive support in this class to ensure your continued academic progress. Class attendance and seating will be recorded (as required by the University) to support contact tracing efforts, however attendance is not mandatory and is not a direct factor in your course grade.

UM policies on Covid-19 and public health are subject to modification as conditions change in the state and Missoula County. Please be flexible and understanding as we prioritize the health and safety of ourselves and of our colleagues while we learn 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 (13% each), a cumulative final exam (26%), and weekly homework sets (35% 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. Regular grade updates will be available on the course Moodle page.

Midterm exams take place during regular class time on the scheduled days unless a longer evening time is selected by agreement of the class. 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 <u>by midnight on the due date</u> (generally Fridays). Assignments will be posted on Moodle, and you will submit your work electronically via Moodle. Upload images (jpg, gif, pdf, etc) of hand-written work, but remember that your work 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! Late homework will be penalized by 10% per weekday to a minimum of 50% (no late work will be accepted after December 10).

Course Schedule & Reading Assignments

			Readings
		STELLAR OBSERVATIONS	
M	Aug 30	Flux and magnitude	3.2
W	Sept 1	Distance, absolute magnitude & luminosity	3.1
F	Sept 3	Filters, color and photometry	3.6
M	Sept 6	*Labor Day Holiday*	
W	Sept 8	Thermal radiation & the Planck function	3.4, 3.5
F	Sept 10	Stellar spectra	5.1
M	Sept 13	Stefan-Boltzmann law & stellar radii	pp 69-70, pp 144-148
W	Sept 15	Binary stars and stellar mass	Ch. 7
F	Sept 17	Solar measurements & radioactive dating	pp 756-759
M	Sept 20	Hertzsprung-Russell diagram	8.2
W	Sept 22	Mass-luminosity relation and MS lifetimes	p 189
F	Sept 24	**Midterm 1**	
		PHYSICS OF STELLAR STRUCTURE	
M	Sept 27	Gravity & hydrostatic equilibrium	10.1
W	Sept 29	Statistical mechanics and PDFs	
F	Oct 1	Pressure integral and the ideal gas law	10.2
M	Oct 4	Stellar interiors & ionization	pp 213-219
W	Oct 6	Radiation pressure	pp 236-237, p. 295
F	Oct 8	LTE and radiative transfer	pp 251-261
M	Oct 11	Opacity and mean free path	9.2
W	Oct 13	Radiative energy transport	pp 315-316
F	Oct 15	Convective energy transport	pp 316-325
M	Oct 18	Equations of stellar structure	pp 329-332
W	Oct 20	Mass-luminosity relation, revisited	
F	Oct 22	**Midterm 2**	
		STELLAR NUCLEOSYNTHESIS	
M	Oct 25	Four fundamental forces	
W	Oct 27	Nuclear reactions & binding energy	pp 298-302
F	Oct 29	Wave/particle duality & quantum tunneling	pp 127-132
M	Nov 1	Nuclear reaction rates & cross sections	pp 302-308
W	Nov 3	Hydrogen fusion	pp 308-312
F	Nov 5	Helium fusion	pp 312-313

M	Nov 8	Heavies fusion	pp 313-315
		STELLAR MODELING	
W	Nov 10	Boundary conditions and integrations	pp. 332-334
F	Nov 12	Computer modeling with MESA code	
M	Nov 15	Computer modeling with MESA code	
W	Nov 17	Solar internal structure models	pp 349-356
F	Nov 19	What determines the mass range for stars?	
M	Nov 22	**Midterm 3**	
W	Nov 24	*Thanksgiving Break*	
F	Nov 26	*Thanksgiving Break*	
		THE SUN AS A STAR	
M	Nov 29	Solar elemental abundances and luminosity	
W	Dec 1	Solar neutrinos	pp 356-360
F	Dec 3	Helioseismology	pp 509-512
M	Dec 6	Solar magnetic field and the sunspot cycle	11.3
W	Dec 8	Solar wind & the corona	11.2
F	Dec 10	Review	
W	Dec 15	**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 💣