Spring 2-1-2022

ASTR 365.01: Stellar Astronomy & Astrophysics

Nathan T. McCrady
University of Montana - Missoula, nate.mccrady@umontana.edu

Astronomy 365: Stellar Astronomy and Astrophysics II

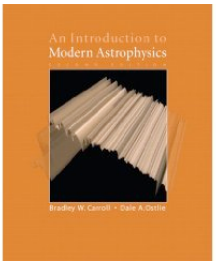
University of Montana
Spring 2022
MWF 10:00 – 10:50 am
CHCB 231
Course Number 34208

Professor Nate McCrady
e-mail: nate.mccrady@umontana.edu
Office Hours: by appointment
Course website: *see Moodle*

Course Description
Stars in the night sky appear fixed and unchanging, eternal. In this course, we will apply our physical understanding of the structure and composition of stars to discover that they are in fact ever-changing objects locked in a constant struggle against gravity. We will begin with the relatively benign life cycle of low-mass stars like our Sun. Next, we will investigate the violent life cycle of high-mass stars. From there we will apply physical principles from mechanics, thermodynamics, statistical mechanics, relativity, and quantum, atomic and nuclear physics to develop a physical understanding of the nature of stellar remnants, the formation of stars, stellar atmospheres and spectroscopy. The unifying theme of the course will be to understand the Hertzsprung-Russell diagram via basic principles of physics. The first semester, ASTR 363, focused on the internal structure of individual main sequence stars. In the second semester, ASTR 365, we will investigate the time evolution of stars, including their birth and end states.

Course Objectives
My goals in this course are to…

1. Apply physics to understand the life cycle and end states of stars.
2. Introduce the physics and phenomena of star formation and the interstellar medium.
3. Develop a physical understanding of stellar spectra.



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

Available from amazon.com (and elsewhere) for ~ $100

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-requisite courses: Astronomy 363 (the first half of this course), Astronomy 132 or 142 (introductory astronomy) and Physics 217 (physics with calculus). It is advantageous if you have also taken Physics 343 (modern physics), but we will study the necessary quantum, atomic and nuclear physics within this course. Integral and differential calculus are essential in this course, and you should have a strong understanding of the pre-requisite Math 273 (multi-variable calculus). You should also be comfortable working

with logarithms, scientific notation and the Greek alphabet. Our class meetings are an essential part of this course, and it will be to your benefit to attend discussions whether in person or online. Exams and homework will be based primarily on material presented in class. This syllabus includes assigned readings. I expect students to read the material in advance of the class on a 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

We begin Spring semester 2022 while a firestorm of the highly-infectious omicron strain of coronavirus engulfs the country. The contagion is currently spreading rapidly in Montana. The best defense against severe illness remains the widely available vaccines – I highly recommend that you protect yourself via vaccination and the booster. Please direct questions regarding covid vaccination to Curry Health Center (243-4330). Ventilation is the second line of defense, and windows will remain open each day in our classroom during this semester. Please dress accordingly, as the fresh winter air can be rather bracing. Use of a mask covering the nose and mouth remains mandatory within the classroom at UM this semester, preferably KN95 or N95 if available. **If you feel sick and/or are exhibiting COVID symptoms, 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 continued academic progress. All class discussions will be available via Zoom, and you need not justify your choice to participate remotely. Let's all be kind, and prioritize our health and well being in this trying time.

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 should be turned in via Moodle by 11:59pm on the stated due date (generally Fridays). Late homework will NOT be penalized, as we are all dealing with some sh-t right now and I would like to allow you flexibility in your life. Do try to stay timely, as the HW is timed to the classroom material, and will help you prepare for exams. Please note that no late work will be accepted after May 9, as I need sufficient time to finish grading. 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 EVOLUTION	
M	Jan 17	*Martin Luther King Holiday*	
W	Jan 18	M.S. evolution and the Virial theorem	2.4, 446-452
F	Jan 21	Core hydrogen exhaustion	452-457
M	Jan 24	Stellar modeling with MESA	
W	Jan 26	Shell fusion and ascent of the RGB	457-461
F	Jan 28	Helium fusing stars	461-463
M	Jan 31	AGB stars and planetary nebulae	463-474
W	Feb 2	Post-MS evolution of high mass stars	518-521
F	Feb 4	Approach to the iron catastrophe	313-315
M	Feb 7	Supernova observations, SN 1987A	15.2
W	Feb 9	Supernovae: collapse, explosive nucleosynthesis	15.3
F	Feb 11	Supernovae, continued	
M	Feb 14	**Midterm 1**	
W	Feb 16	Wolf-Rayet stars and gamma ray bursts	521-523, 15.4
F	Feb 18	Variable stars and the instability strip	14.1
M	Feb 21	*Presidents' Day Holiday*	
W	Feb 23	Interacting binaries and Type Ia supernovae	18.1, 18.5
		STELLAR REMNANTS	
F	Feb 25	White dwarfs	16.1-16.2
M	Feb 28	Degeneracy pressure, Chandrasekhar mass	16.3-16.4
W	Mar 2	Neutron stars	16.6
F	Mar 4	Pulsars	16.7
M	Mar 7	Black holes and the Schwarzschild metric	17.1, 622-633
W	Mar 9	Astrophysical black holes	633-646
F	Mar 11	Black holes, continued	
M	Mar 14	**Midterm 2**	
		STAR FORMATION AND THE ISM	
W	Mar 16	Gas phases in the interstellar medium	398-399, 431-432
F	Mar 18	Interstellar dust and extinction	399-404
		Spring Break	
M	Mar 28	Atomic gas	404-406
W	Mar 30	Radio astronomy	6.3
F	Apr 1	Molecular clouds	406-411

M	Apr 4	Pre-MS evolution: protostars and disks	12.2
W	Apr 6	Pre-MS evolution: the Hayashi track and birthline	425-429
F	Apr 8	Pre-MS evolution, continued	
M	Apr 11	T Tauri stars and Herbig Ae/Be stars Star clusters	434-441
W	Apr 13	and the initial mass function	430, 474-477
F	Apr 15	Brown dwarfs	Supplement
M	Apr 18	**Midterm 3**	
		STELLAR ATMOSPHERES	
W	Apr 20	Radiative transfer and the source function	255-258
F	Apr 22	Plane parallel atmosphere	258-263
M	Apr 25	Detailed balance and Einstein coefficients	Supplement
W	Apr 27	Line broadening and equivalent width	267-271
F	Apr 29	Radiative transfer, continued	
M	May 2	Theory of spectral line formation	271-273
W	May 4	Curve of growth	273-276
F	May 6	Review	
Th	May 12	**Final Exam, 10:10am – 12:10pm**	

Additional Reading

There are many excellent texts on the subjects of stellar astrophysics and the interstellar medium, many of which will be 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

Supernovae and Nucleosynthesis, D. Arnett, 1996

Black Holes and Time Warps, K.S. Thorne, 1995

Black Holes, White Dwarfs and Neutron Stars: The Physics of Compact Objects, S.L. Shapiro and S.A. Teukolsky, 1983 ★

Gravity: An Introduction to Einstein's General Relativity, J.B. Hartle, 2003

The Formation of Stars, S.W. Stahler and F. Palla, 2004

Physics and Chemistry of the Interstellar Medium, S. Kwok, 2007

The Observation and Analysis of Stellar Photospheres, D.F. Gray, 1983 ★

Introduction to Stellar Astrophysics, Vol. 2: Stellar Atmospheres, E. Böhm-Vitense, 1989

Astronomical Masers, M. Elitzur, 1992